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ABSTRACT

Presented is a manuscript for an introductory boiler water chemistry course for marine engineer education. The course is modular, self-paced, audio-tutorial, contract graded and combined lecture-laboratory instructed. Lectures are presented to students individually via audio-tapes and 35 mm slides. The course consists of a total of 17 modules - eight required, four elective, and five attending to remedial mathematics skills. The laboratory consists of eight learning stations each of which will accommodate two students. Course objectives include: (1) introduction to fundamentals of chemistry; (2) provide basic skills in boiler water analysis; (3) provide understanding of problems caused by faulty boiler water treatment; and (4) provide understanding of boiler water treatment to minimize damage to ship's boilers. (SL)

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AN INTRODUCTION TO BOILER WATER CHEMISTRY FOR THE MARINE ENGINEER: A TEXT OF AUDIO-TUTORIAL INSTRUCTION

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INTRODUCTION

An Introduction to Boiler Water Chemistry for the Marine Engineer attempts to attend to the varying abilities and interests of a variety of students. It is a modular, self-paced, audio-tutorial, contract graded course. This means that the student decides what competency level he wishes to attain (this is accomplished through the grade contract) then proceeds, at his own rate using the audio-tutorial approach, to attain that level.

The course is a combination lecture-laboratory course. The lectures and discussions of the various concepts are presented to the student via audio-tape, and essential features are emphasized with 35mm slides. For students who prefer to read rather than listen, tapescripts may be checked out from the instructor. (The tapescripts contain exactly the same information as do the audio tapes.) Laboratory exercises are included in the modules where they are relevant. When the student encounters a laboratory activity he is expected to stop, conduct the activity, gather the data, etc., and then proceed.

The course is composed of seventeen modules. Eight of the modules are required in order to attain the various competency levels. In addition, there are four elective modules, and five modules which attend to remedial mathematics skills.

Successful completion of the course requires that the student spend approximately three hours each week of in-class time. The instructor has a schedule listing the times each week during which the laboratory-classroom is open. The laboratory is designed for eight learning stations and each station will accommodate two students. The laboratory is open each week for a time sufficient to allow each student the required three hours of in-class time plus approximately one additional hour. In order to avoid confusion, students are requested to reserve a learning station for at least three hours during the week. That station will then be available for the respective student's use during the time for which he has reserved it.

It is assumed that a student who reserves a learning station will be present during his reserved time. If the station is not occupied by ten minutes after the beginning of the hour for which it is reserved, it may be considered as open and so available for any other student's use.

Finally, any learning station may be used at any time when it is not reserved. A schedule is posted by each station showing the names of the students who have reserved the station, the times during which the station is reserved, and the times during which the station is available for general use (not reserved).

Each student is required to keep a time card. The time cards are to be left in the classroom-laboratory. When a student comes to use a learning station, he should pick up his time card (stored in the containers near the classroom door). Then, when he is ready to leave, he should have the time card initialed by the instructor.

OBJECTIVES

The objectives of the course are:

1. To introduce the student to the fundamentals of chemistry.

2. To provide the student with basic skills in the area of boiler water analysis tests.

3. To provide the student a basic understanding of the problems caused by faulty boiler water treatment.

4. To provide the student with an understanding of what types of boiler water treatments will minimize damage to boiler tubes caused by the mineral content of water and maximize the life of the ship's boilers.

COURSE GRADE

The course grade is determined by contract. That is, the student decides the competency level he wishes to attain and then contracts to do the work necessary to attain that level.

The grading policy is also open-ended. The student is expected to fill out a grade contract during the first week of the semester indicating the grade for which he intends to work. However, if anytime during the semester, but not later than the last week of classes, the student finds his original contract to be unrealistic he may down-contract. If, on the other hand, he finds the grade for which he originally contracted to be too low, he may raise his contract.

The following requirements are established as minimums:

If the student wishes to attain the D competency level (a D level contract) he must successfully complete Modules D1 and D2.

A grade of C requires that the student successfully complete Modules D1, D2, C1, C2, C3, and C4.

In order to obtain a grade of B, the student must meet the requirements for the D and C grades and in addition he must complete Module B1 plus two elective Modules (E1 through E4).

A student who wishes to attain the A competency level must meet all of the requirements for the D, C, and B competency levels plus Module A1 and a third elective Module.

If a student should fail to meet the requirements of his contract, the contract will be voided. In this case, all of the student's previous work will be evaluated. If that work has been exceptional, the student may possibly be awarded the grade for which he originally contracted. If, on the other hand, all of the student's work has been marginal, he might expect the grade to drop at least one grade below that of the originally contracted grade. In any event, if a student fails to meet his contract, the grade will then be determined by the instructor.

ATTENDANCE POLICY

The course does not carry a mandatory attendance policy. However, although there is no required attendance policy, the student is expected to spend sufficient time in order to meet his contract grade obligations. Once the student meets the obligations of the grade for which he has contracted, he need not return to the laboratory-classroom for the remainder of the semester. A specified amount of material must be mastered. After mastery has been demonstrated the student will be awarded the grade for which he contracted. This, however, should not be misconstrued to mean the student needs to complete his work prior to the the end of the semester. Each student is welcome to work up to and including the last day of classes preceding the final exam period.

EXAMINATIONS

After the student has completed what he considers to be sufficient study on a module, he sould contact an instructor concerning an examination over material covered in the module.

Some of the end of module examinations are essay, some require short answers, some require the student to solve problems and balance chemical equations, and in some isolated cases examinations may be oral. All of the exams are pass/fail.

A pass on an examination means that the student has learned the material well enough to be considered minimumly competent with the subject matter dealt with in the module. A failure on an exam indicates that the student has not yet learned the material in a module to a level sufficient to demonstrate minimum competency. A student may take as many exams as are necessary in order to receive a passing grade. However, a student may not take more than one examination on the same day.

There are ten different examinations for each module. A student does not take the same examination twice over a given module. Finally, a pass on an examination means that a student has answered 90% of the items correctly on the examination.

All examinations will be administered during one three hour period each week. The examination period will be posted. Regardless of which module a student is completing, the exam will be taken during the exam period.

PROBLEM SETS

Each module has an associated problem set. These problem sets are taken from the supplementary text and related to the respective module and the course in general. The problem set for each module must be successfully completed (70%) as part of the module requirement. In addition, the student must complete the problem set and have it graded prior to taking the end of the module examination for the first time.

COURSE TIME LINE

The only time limitations on completion of modules exists at the D level. All students must have completed the D1 module, its associated problem set, and have taken the first D1 end of module examination not later than the end of the testing session during the fourth week of classes.

Equipment for the D2 module will be set up starting the third week of the semester. The equipment will remain set up until the end of the seventh week of classes. All students must have completed the D2 module, the D2 module problem set, and be prepared to take the D2 end of module examination not later than the end of the seventh week of classes.

MODULE OUTLINES

1. Module D1, Elementary Background

    A. Substances and Mixtures
    B. Physical properties (phase, density, solubility, luster, ductility, malleability, tenacity, brittleness)
    C. Classification of matter (elements, compounds, mixtures)
    D. Nuclear model of the atom (electrons, protons, neutrons)
    E. Electrovalence and covalence
    F. Periodic Table, its purposes and arrangement
    G. Writing formulas and equations
    H. Solutions (ions in solution, processes of ionization and dissociation, reactions in solutions)

2. Module D2, Low Pressure Boiler Water Treatment

    A. The need for boiler water treatment including corrosion prevention, scale prevention and foaming and carry-over prevention.
    B. Performance of alkalinity, chloride, phosphate, sulfate, hydrazine, total dissolved solids, and soap hardness tests

3. Module C1, Chemical Reactions
    - A. A review of symbols and equations
    - B. Chemical reactions and equations (synthesis, single replacement, exchange of ions, decomposition, combinations of reaction types)
    - C. Electronic equations (electrochemical, electrolytic, simple electrode reactions)

4. Module C2, Quantitative Relationships
    - A. Determination of atomic and molecular weights
    - B. The concept of the mole
    - C. The study of simple weight-weight, weight-volume, and volume-volume problems

5. Module C3, Solutions
    - A. Measurement of concentrations
    - B. A study of the concepts of saturation, supersaturation and the limits of solubility
    - C. The numerical aspects of solutions (percent solution, ppm, gpg, molarity, normality)
    - D. Factors affecting solubility
    - E. Reactions which occur in solution (acid-base neutralization, pH and its effect on scale and protective coatings)

6. Module C4, Corrosion
    - A. The effects of corrosion
    - B. The causes of corrosion (oxygen, carbon dioxide, acid and caustic causes, ammonia, stress, velocity, hydrogen, embrittlement)

7. Module B1, Chemical Reactions
    - A. Energy effects in chemical reactions (temperature, heat and its measurement, heat content, heat of reaction, conservation of energy)
    - B. Rates of reaction (activation energy, catalysis)
    - C. Equilibrium (open and closed systems, factors affecting equilibrium, equilibrium constants, pH, precipitation)

8. Module A1, Atomic Theory
    - A. Spectra, their causes and interpretations
    - B. The Bohr model
    - C. Atom shell populations and energy levels
    - D. The Periodic Table and electron configurations
    - E. Electron configurations and bonding types

9. Module E1, Organic Chemistry
    - A. The characteristic of carbons
    - B. Structural formulas
    - C. Classification of organic compounds (aliphatic, aromatic, substitution products)

10. Module E2, Toxic Substances
    - A. Classification of toxic substances
    - B. Examples of physiological effects of each class (corrosive, metabolic, neurotoxic, mutagenic, carcenogenic)
    - C. Halucinogens

11. Module E3, Water Pollution and Waste Treatment
    - A. Natural water purification
    - B. Pollution types (thermal, sewage, fertilizers, syndets, pestacides, industrial wastes, silt)
    - C. Water purification (common municipal systems, hard water and sea water, distillation, freezing, hydrate formation, ion exchange, electrodialysis, reverse osmosis)

12. Module E4, High Pressure Boiler Water Treatment
    - A. Constraints of high pressure systems
    - B. The coordinated phosphate theory
    - C. The Ultra Marine System of Drew Chemical Company
    - D. Special trace element tests.
    - E. Special analytical methods.
    - F. Automated systems

Modules R1 through R5 are not discussed here. They are remedial in nature and are available for those students who encounter mathematical difficulties as they proceed through the various other modules. They are not to be used as elective modules.

PROCEDURES

1. The student picks up his time card and fills in the time he entered class.

2. The students works on a module at his own pace.

3. The student does the laboratory activities which are required by the module.

4. The student works on and completes the problem set associated with a given module.

5. The student, upon completing a module, contacts an instructor in order to take the end of the module examination.

6. The student beings the next module.

7. Upon departure from the classroom-laboratory, the student fills in his departure time on his time card and then has the instructor initial the card.

MATERIALS

1. Each learning station requires one slide projector and one audio tape player.

2. Audio cassette tapes for each learning station. There should be one tape of each module for each learning station.

3. Slide carrousels for each learning station. There should be at least one set of slides for each learning station of modules D1, D2, C1, C2, C3, and C4. In addition, it is advisable to have at least one set of slides each for modules B1, A1, E1, E2, E3, E4, R1, R2, R3, R4, and R5 for each learning station.

4. Sufficient quantities of equipment and chemicals so that students can perform the various laboratory experiments required by the modules.

5. Reference texts and other paper aids for the students.

SAMPLE GRADING CONTRACT FOR Ch-1

The course grade will be determined by contract.

1. For a grade of D, the student must complete modules D1 and D2.

2. For a grade of C, the student must complete modules D1, D2, C1, C2, C3, and C4.

3. For a grade of B, the student must complete modules D1, D2, C1, C2, C3, C4, B1, and two E modules (E level modules).

4. For a grade of A, the student must complete modules D1, D2, C1, C2, C3, C4, B1, A1, and three elective modules (E level modules).

The student may up or down contract at any time prior to the last week of class during the semester.

Name ________________________________ Date ____________________

Identification Number ________________

I wish to work for a grade of ________________

SAMPLE TIME CARD

LAST NAME FIRST CLASS

STUDENT I.D. NO.

STUDENT SCHEDULE DAY HOUR

WEEK BEGINNING	HOURS					EXAMINATION NO.									
					MOD.	1	2	3	4	5	6	7	8	9	10
1/1					D1										
1/8					D2										
					C1										
					C2										
					C3										
					C4										
					B1										
					A1										
					E1										
					E2										
					E3										
					E4										

THE TEXT

The text contains the tapescripts for the various modules, the problem sets for each module, the solution sets for each problem set, the end of module examinations, the solution sets for each examination, an outline of laboratory activities, a bibliography, and a list of stock solutions necessary to run the various laboratory activities.

Tapescripts. The tapescripts are printed exactly as they are recorded on the audio tapes. This feature allows the student the choice of either reading or listening, or both if he desires dual sensory input of information. He can both read and listen simultaneously. In addition, the tapescript is printed on the left half of the page, leaving the right half of the page for either a stylized version or a typed version of each slide. In cases where a stylized version would not fit into the space allocated for the slide, that slide is included on an "A" lettered page following the page on which it should be located. For example, if slide number twenty-five should be located on page 10 but there is insufficient room on page 10, then stylized slide number twenty-five is located on page 10A. Finally, in some cases where it was not practical to stylize a slide, the names appearing on the actual slide are typed in the area reserved for that slide.

Use of stylized slides allows greater flexibility in attending to a variety of learning styles. Since the tapescripts are available for use in the lab, the student may read the tapescript and view the stylized slide, read the tapescript and view the real slide, listen to the tapescript and view the stylized slide, listen to the tapescript and view the real slide, or use any combination of these four together.

The actual combination used by each student is a function of his preferred learning style.

In some instances or learning situations it is desirable to provide students with their own copies of the tapescripts (the student pays the printing costs). When students have their own tapescript text they may choose to use the text also as a notebook. There is ample room to do this on the halves of the tapescript pages. In most cases, there is sufficient room to place relevant notes either to the right of the related text material or above and below the related stylized slide. The feature serves to organize student notes into a coherent and useful sequence.

Problem Sets. The problem set for each module is taken from Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. Each problem set is designed to support the material presented on the tapescript and in the slides. Each problem set sheet also includes a list of supporting pages in Miller and Augustine. The pages that are listed support the problem set as well as the respective module.

Problem Set Solutions. Problem set solutions are provided for each problem set. They are provided primarily for instructor use. In most cases the problem setups are included with the respective problems, a feature which allows the instructor greater flexibility in allowing or not allowing credit for a given problem.

End of Module Examinations. There are ten end of module examinations for each module. Since students are allowed to take examinations more than once if need be to demonstrate minimum competency over material contained in a module, the intent is not to give the same exam twice. The number of examinations available also allows instructor flexibility in his or her end of module testing. In cases where more than one testing session is required to test all students once over a given module, the instructor may use a different examination over the same module at each different testing session without violating the confidence of any examination (at least for the first testing).

Examination Solution Sets. Examination solution sets are provided for each examination. Where possible, problem setups have been included in an effort to decrease the amount of time required for correction.

Bibliography. The bibliography includes not only the text material required to support the modules but also additional boiler water analysis literature.

Laboratory Activities and Stock Solutions. The laboratory activities are listed by modules and listings of the stock solutions which are used in Modules D2 and D4 are included.

ACKNOWLEDGMENTS

Many students and people in other academic and staff categories were of invaluable assistance in the conduct and completion of this writing. Special notes of appreciation are given to Dr. John Barlow and Mrs. Dorothy Small for their help in pointing out many errors that had been overlooked. A special note of appreciation is also given to Mrs. Frances Tudan who graciously corrected many errors as she tirelessly typed the manuscript. Any remaining errors are entirely the responsibility of the author.

Richard M. Schlenker
Maine Maritime Academy
January 1978

MODULE D-1 ELEMENTARY BACKGROUND

Module D-1 is the first of several modules which you will be required to study as you progress through the course titled, An Introduction to Boiler Water Chemistry for the Marine Engineer. The module is intended to introduce the student to some of the elementary concepts in chemistry. If you already have some chemistry then this module should prove an excellent review. This module then contains the definitions of concepts and models which are the basic vocabulary of chemistry. The concepts presented in the module are phase, density, solubility, luster, ductility, malleability, tenacity, brittleness, homogeneous, molecule, solvent, solute, element, symbol, acid, base, salt, indicator, neutralization, organic compounds, colloid suspension, tendell effect, atom, electron, proton, neutron, isotope, ion, electrovalent bond, ionic bond, covalent bond, ionization, dissociation, precipitation, formula, equation, radical, relationships among substances, mixtures and compounds, kinetic-molecular theory, organization of the periodic table, a simplified Bohr model of the atom, and the Law of Definite Proportions. As a result of studying this module, the student will be able to define, discuss and give examples of the various concepts listed in the paragraph above.

Advance your slide carrousel to slide number one. In this slide, three definitions are presented which you perhaps already know. A substance is a variety, all specimens of which have identical properties and composition. Water (H_2O) is an example of a substance, and no matter what the source, pure water is always the same.

A substance is a variety of matter, all specimens of which have identical properties and composition.

Substances are homogeneous.

A mixture consists of two or more distinct substances differing in properties and composition.

SLIDE #1

Substances are homogeneous, that is, they are the same throughout. Let us consider pure water again. All portions of pure water are the same.

A mixture is composed of two or more distinct substances. These substances differ in their properties and composition. A mixture may not be homogeneous throughout. For example, sand and water is a heterogeneous mixture. That is, they may be separated into their component parts. Salt and water is a homogeneous mixture since it cannot be readily separated.

Look at slide number two. Salt (NaCl) is a pure substance consisting of sodium (Na) and chlorine (Cl) chemically bonded together. All samples of salt (NaCl) will have identical compositions. Salt and pepper are a mixture. The substances are distinct as can be seen in the mixture. The pepper may or may not be evenly distributed in the salt. That is, the mixture may or may not be homogeneous. However, salt is always homogeneous.

SALT AND PEPPER with a pile of salt in front of the salt shaker and a pile of pepper in front of the pepper shaker.

SLIDE #2

Advance your carrousel to slide number three. The mixture you see is sand and iron filings. The iron filings may be separated from the sand because they are magnetic, while the sand is not. Generally, mixtures may be separated by physical means. The components of substances cannot be physically separated.

Two piles of sand and iron filings mixed with a magnet held close to one pile.

SLIDE #3

Look at slide number four. Materials dissolved in water constitute a mixture which can be separated by boiling. If, for example, steam can escape from a boiler, soon all that is left is a mineral residue.

Two 250ml beakers. One beaker contains a solution while the other beaker contains the solute after the water has been boiled off.

SLIDE #4

Look at slide number five. So far we have talked about substances and mixtures. Can you write their definitions? See if you can and then compare your definitions with those on slide number one.

SUBSTANCE
HOMOGENEOUS
MIXTURE

SLIDE #5

Now, advance your carrousel to slide number six and let us consider some physical properties. The term, phase, is used to refer to the form of matter.

Matter may exist as a solid, a liquid, or a gas. Gases are a form of matter which has neither definite form nor definite shape. Liquids have definite volume but not definite shape. Solids have both definite volume and definite shape.

Look at slide number seven. Obviously, its a drop of water and isn't very large. But consider how much smaller it could be made. It could be cut in half, and one of the quarters in half; and so on seemingly to infinity. But can this go on to infinity? Is there a limit to how small a drop of water can be, and still be a drop of water? If your answer was yes, you were correct.

The ancient Greeks considered this question and decided there was a limit. They then coined a word for this limit. They called the ultimately small particle an atom. Today we know that the smallest particles of everything but elements can be broken down to elements. For

The term "phase" is used to refer to the gas, liquid, or solid form of matter.

Gases have neither definite shape or volume. They assume the shape and volume of their container.

Liquids have a definite volume, but take the shape of their container.

Solids have definite shape and volume.

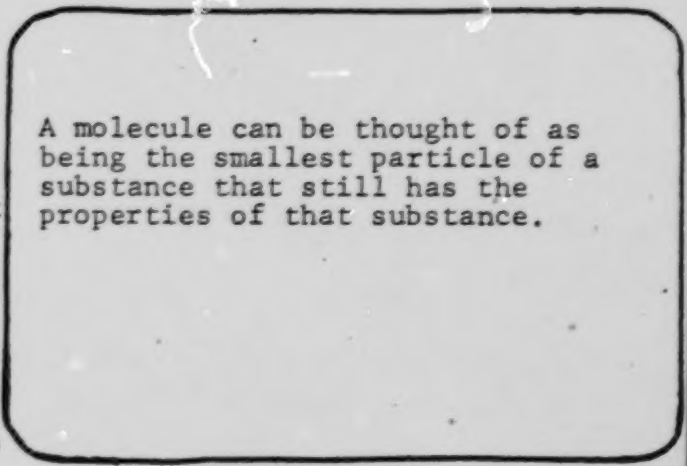
SLIDE #6

SEVERAL WATER DROPLETS ON A LEAF.

SLIDE #7

most substances; however, the limiting particle is called a molecule. Water (H_2O) then can be divided only to the point where there is one molecule. At this point, further division requires that the molecule be broken into its component hydrogen (H) and oxygen (O) atoms.

Look at slide number eight. A molecule can be thought of as being the smallest particle of a substance that still has the properties of that substance.

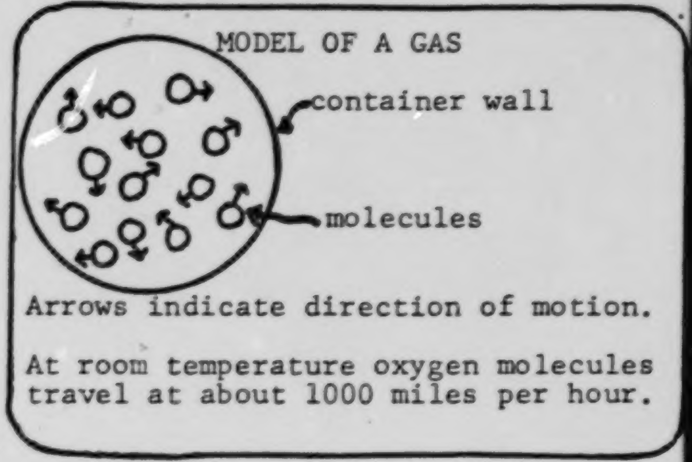


A molecule can be thought of as being the smallest particle of a substance that still has the properties of that substance.

SLIDE #8

Now advance your carrousel to slide number nine. The state of matter (solid, liquid or gas) depends on the energy level of the molecules. In the gaseous state they have enough energy to break free of each other and if they collide, the collision is violent enough to prevent their sticking together.

They bounce off the walls of their container. The force of the collisions with the wall causes what we call pressure. Obviously then, their speed upon impact with a



MODEL OF A GAS

Arrows indicate direction of motion.

At room temperature oxygen molecules travel at about 1000 miles per hour.

SLIDE #9

container's walls is proportional to the force which they create. For example, at room temperature oxygen (O_2) molecules have a speed of 500 meters per second, or 1,000 miles per hour.

In the liquid and solid states atoms or molecules do not have enough energy to break the forces of attraction between them. In the solid phase they line up geometrically much as spheres might be expected to do. Note that molecules are stationary in the solid phase; however, this does not mean that they do not have motion. On the contrary, they vibrate and rotate in place. Look at slide ten. Here you will find an illustration of the concept we have just talked about. In the liquid phase atoms or molecules, as the case may be, have enough energy to break out of the geometric pattern but not enough to separate.

Three cubic containers, one showing particles in the gaseous state, one showing particles in the liquid state, and one showing the arrangement of particles in the solid state.

SLIDE #10

Not all molecules have identical energies at any given time. Some may be stopped while others move very rapidly. This accounts for the phenomenon we call evaporation.

Now advance your slide carrousel to slide number eleven. If a surface molecule acquires enough energy to break the forces holding it to its neighbors, it might "pop" out of the surface and become a free gas molecule. It aquires this energy by collisions with other fast moving molecules that hit it from below.

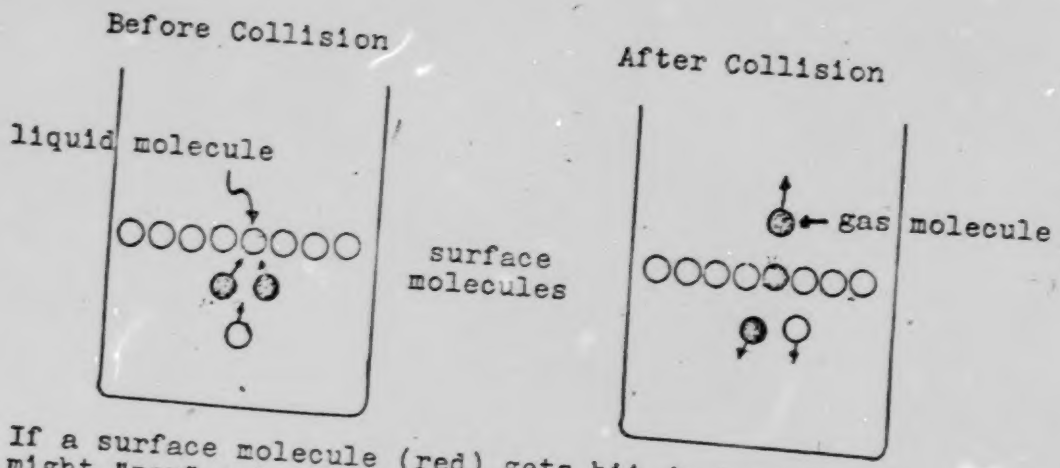
See Page 8A -- following

SLIDE #11

Let us, for a moment, discuss what you might be expected to know about information presented in the preceding discussion. You should be able to recognize and name the definitions of the terms used. The terms were substance, homogeneous, mixture, phase, molecule, evaporation, gas, liquid, and solid. You should recognize that matter cannot be divided into smaller pieces indefinitely. In addition, you should realize that the difference in phase is due to energy differences in molecules and what the relative differences are. Finally, you should be able to explain evaporation in terms of molecules and energy.

MODEL FOR EVAPORATION

SLIDE #11


Before Collision
After Collision
liquid molecule
surface molecules
gas molecule

If a surface molecule (red) gets hit just right, it might "pop" out of the surface to become a gas molecule.

Look at slide number twelve. Density is another term frequently used to describe materials. Density is the ratio of mass to volume, or D=M/V. Sometimes density is defined as the weight to volume ratio. These are the definitions that you must know in order to do your calculations.

Density = $\frac{\text{mass}}{\text{volume}}$ D = M/V or m/v

For example:

D = grams/cubic centimeter or g/cc

D = kilograms/liter or kg/l

D = grams/milliliter = g/ml

Sometimes weight density:

D = pounds/cubic foot = lb/cuft
= lbs/gallon

SLIDE #12

At this point, I would like you to find the density of two liquids. This is done by measuring their volume with a graduated cylinder and weighing the cylinder empty and with the liquids in the cylinder. The weight of the empty cylinder is then subtracted from the weight of the full cylinder to yield the weight of the liquid. In reading the cylinder you must line up the bottom of the curved surface, called the meniscus, with the graduation marks to obtain an accurate reading. Look at slide number thirteen.

A graduated cylinder showing a meniscus at 96.4ml.

SLIDE #13

A triple arm balance, graduated cylinder, and four 250ml sample bottles marked A, B, C and D. The sample bottles contain four different solutions (different colored solutions).

SLIDE #14

Now look at slide number fourteen. It shows the materials you will need to perform the experiment. If you do not know how to use the balance, please read the instructions. If, after reading the instructions, you are still unsure of the operation, seek the aid of a fellow student or your instructor. Now you should proceed with your experiment. When you have finished, rinse out the graduated cylinders and show your data, calculations and results to your instructor.

Advance your slide carrousel to slide number fifteen. Let us consider solutions. Slide number fifteen lists some basic terms related to solutions. A solvent is a material in which another dissolves. The solute is the dissolved material. Solubility is the ability, or a measure of the ability, of a material to dissolve in another. For example, if sugar dissolves in water, it is said to be soluble. The sugar is the solute; the water is the solvent.

Define: SOLVENT
SOLUTE
SOLUBILITY

SLIDE #15

You should be able to recognize the definitions of these terms.

Look at slide number sixteen and let's consider some other descriptive terms. Luster is the silvery shine

Luster is the silvery shine of many materials -- particularly metals.

Slide shows a shiny brass and steel padlock.

SLIDE #16

of many materials, particularly metals.

Look at slide number seventeen. Malleability is the ability to be pounded into thin sheets. It is the opposite of brittleness.

Malleability is the ability to be pounded into thin sheets.

Slide shows a piece of metal drawn into a long, thin shape.

SLIDE #17

Look at slide number eighteen. Ductility is the ability to be drawn into a wire. Tenacity or tensile strength is the ability to resist being pulled apart. Brittleness is the tendency to shatter when struck with a sharp blow. Electrical conductivity is the ability of a substance to pass an electric current.

Ductility is the ability to be drawn into a wire.

Tenacity, or tensile strength, is the ability to resist being pulled apart.

Brittleness is the tendency to shatter when struck with a sharp blow.

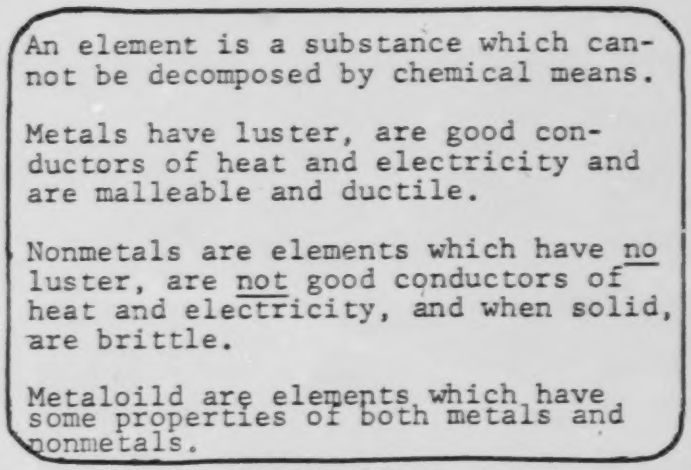
Electrical conductivity is the ability of a substance to pass an electric current.

SLIDE #18

These are basic terms used to describe matter. You should be able to recognize and name their definitions. Can you define them? You might stop for a moment and try.

Let us consider how matter may be classified. The usual basic scheme used by chemists is to classify matter as elements, compounds, and mixtures. We'll consider them one at a time.

Look at slide number nineteen. An element is a substance which cannot be decomposed by chemical means. A key word here is "chemical means". Elements can be changed by thermonuclear reactions or fission reactions.



An element is a substance which cannot be decomposed by chemical means.

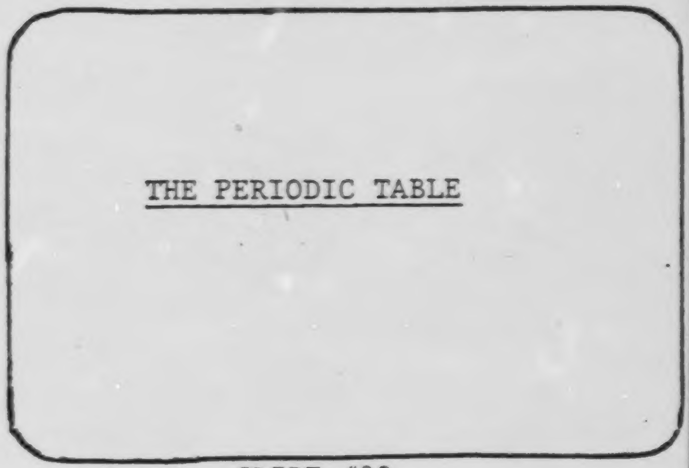
Metals have luster, are good conductors of heat and electricity and are malleable and ductile.

Nonmetals are elements which have no luster, are not good conductors of heat and electricity, and when solid, are brittle.

Metaloild are elements which have some properties of both metals and nonmetals.

SLIDE #19

Advance your carrousel to slide number twenty. The symbols on the chart represent the name of an element. In the upper right hand corner "H" stands for hydrogen; "Li" below it for lithium, and so on. The arrangement of the chart is by increasing atomic number. Generally this means that as the mass of the atom increases, the atomic number increases. Hydrogen is the lightest element known, Helium is the next lightest, and so on. The chart is so arranged so that verticle columns contain elements that are chemically similar. In the first column, Lithium (li), sodium (Na), Potassium (K), and rhubidium (Rd), for example, react with other elements in a very similar fashion.



THE PERIODIC TABLE

SLIDE #20

Notice the heavy step wise line near the middle of the chart. This line separates the metals from the non-metals. The metals are to the left of the line and the non-metals to the right.

Generally speaking, as one proceeds across a horizontal row or period, the elements become increasingly nonmetallic in character. The last column starting with Helium at the top, is the inert element column. This column could also be considered the divider between metals and non-metals.

The majority of elements are metals; they have lustre, are good conductors of heat and electricity, are malleable and ductile. All metals except mercury are solids at room temperature.

All non-metals, except bromine, are gases or brittle solids: they have no luster and are poor conductors of heat and electricity.

The elements along the zig-zag line but to the right of it, are called metaloids. These have properties of both metals and non-metals. Sometimes these properties are strange. Silicon, for example, under the right conditions, conducts electricity, but only in one direction.

The last few minutes of discussions contained many ideas and discussions of definitions. I would suggest that you reread or relisten to this section. The definitions that you will be expected to recognize are found on slide number twenty-one.

ELEMENT
METAL
NONMETAL
METALOID

Numerical arrangement of the periodic table of Elements.

Verticle arrangement of the periodic table.

Horizontal arrangement of the periodic table.

SLIDE #21

Look at slide number twenty-two. A compound is a substance which can be decomposed by chemical change. A compound is composed of 2 or more elements. All samples of a compound have the same composition. Furthermore, the elements which are present in a compound are present in a definite ratio which cannot be varied.

A compound is a substance which can be decomposed by chemical means.

A compound is made up of two or more elements.

All samples of a compound have the same composition.

The elements in a compound are present in a definite mass ratio which cannot be varied.

SLIDE #22

Look at slide number twenty-three. After this explanation find an electrolysis apparatus and note the readings on the burettes. Allow the apparatus to run 10 or 15 minutes and note the readings again. Subtract

SLIDE SHOWS Electrolysis equipment.

SLIDE #23

each reading from the initial reading for that burette and find the ratio of the volume of hydrogen to oxygen. This ratio is invariant.

Now look at slide number twenty-four. Let us consider the classification of compounds. One way to classify them is into acid bases, salts and organic compounds.

Acids have a sour taste -- lemon is acid.

Acids affect indicators. Phenolphthalien turns colorless in acid. Tea becomes lighter when lemon is added.

Acids neutralize bases, that is, acids counteract the effect of bases, and vice versa.

Acids react with metals to produce hydrogen, and of course, destroy the metal.

Acids react with carbonates to liberate CO_2. This property is often used in minerology to identify carbonate minerals.

Advance your carrousel to slide number twenty-five.

Now look at slide number twenty-six. It shows the equipment needed to illustrate the effect of acids and bases on indicators. You should gather together these pieces of

Acids are a class of compounds which:

have a sour taste

affect the color indicators

neutralize bases

react with metals to produce hydrogen

react with carbonates to liberate carbondioxide

SLIDE #24

WARNING: STRONG ACIDS AND BASES

DESTROY LIVING TISSUE.

HANDLE WITH CARE.

If you come in contact with strong reagents, flush with water immediately.

SLIDE #25

SLIDE SHOWS two liter bottles, one containing dilute acid and one dilute base; a small bottle of phenolphthalein; two 50ml beakers; one 250ml beaker; one test tube; and two eyedroppers.

SLIDE #26

equipment.

Pour a small amount of acid and base into separate beakers. Pour base into a test tube until it is about 1/8 to 1/4 full and add 1 drop phenolphthalien. With an eye dropper add acid in a dropwise manner until the color disappears. As this step is accomplished you will need to agitate the liquid. The color can best be seen by holding your test tube against a white background. After the color has disappeared, add a few drops of base till the color reappears.

At the point where the color appears and disappears, the acid and base have neutralized each other and the solution will not be either acid or base, but rather a salt. The process of finding the balance (neutral) point, so to speak, between acid and base is called titration. Titration will be used in the next unit to analyze boiler water.

When you have finished, discard the extra acid or base, rinse the beakers and eye droppers and put the materials away. Do not return any of the acid or base to their reagent bottles.

Look at slide number twenty-seven. In slide number twenty-seven you will see the materials necessary to demonstrate that acids react with metals. Now you should gather those materials.

SLIDE SHOWS one bottle containing dilute H_2SO_4, a few pieces of zinc, one 250ml beaker, and one test tube.

SLIDE #27

Add a small amount of acid to a piece of mossy zinc in the test tube. The bubbles that form are hydrogen and if you hold a match near the mouth of the test tube, it should burn.

Pour off the acid, add water to the test tube with the zinc in it. Repeat this step 2 or 3 times and then return the materials. Put the zinc in the waste zinc container. Do not put the zinc down the drain.

Look at slide number twenty-eight and gather the materials shown in that slide.

SLIDE SHOWS one liter bottle containing dilute acid, a bottle of marble chips, and a test tube.

SLIDE #28

Place a marble chip in the test tube and add some acid. Try to ignite the gas that comes off. Is it hydrogen?

When you have finished your observations, clean and return all of your materials.

Advance your carrousel to slide number twenty-nine. A salt can be thought of as the product of the neutralization of any acid and any base. An acid and a base always combine to form salt and water, and most salts are found in minerals of the earth and in sea water. Table salt is a most common example.

See Page 18A -- Following

SLIDE #29

Look at slide number thirty. Organic compounds are compounds of carbon. Methane, or natural gas consists of a carbon atom with 4 carbons attached. Octane in gasoline has the configuration which is shown. Sugar also is a carbon compound.

See Page 18B -- Following

SLIDE #30

Carbon atoms have the unusual property of being able to attach to each other to form long chains. This chain structure is a common characteristic of organic compounds.

Some compounds of Carbon are not considered to be organic. For example, limestone, which is calcium carbonate, is not organic. There are, however, not many of these compounds.

SLIDE #29

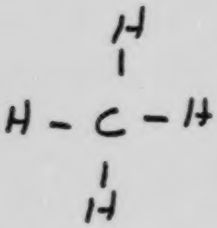
A salt, which is a combination of a metal and a nonmetal, can also be considered to be the product of the neutralization of any acid and any base.

ACID + BASE → SALT + WATER

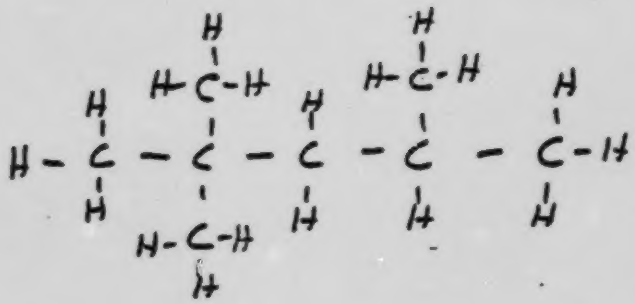
hydrochloric acid + sodium hydroxide → sodium chloride + water

acetic acid + ammonium hydroxide → ammonium acetate + water

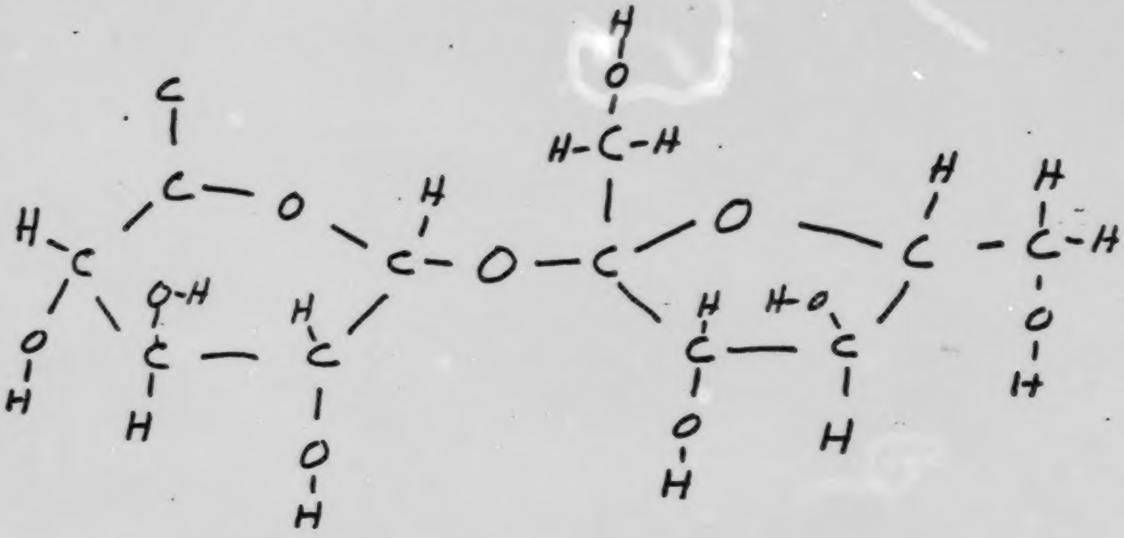
Slide 30



methane



octane



ordinary sugar

Look at slide number thirty-one. A mixture, you will recall, consists of 2 or more distinct substances. A suspension is a mixture containing particles of one substance distributed through another. Particles in suspension usually settle out. The muddy water in slide thirty-one will eventually clear. Most suspensions are of this kind.

SLIDE SHOWS a 250ml beaker containing muddy water.

SLIDE #31

Look at slide number thirty-two. Some suspensions, however, do not settle out. If the particles in suspension are small enough, the suspension is stable. Smoke is a common example of this type of suspension. Suspensions of this kind are called colloids. Colloidal suspensions may occur in the liquid or gas phase. Colloidal suspensions, or dispersions, as they are sometimes called, have the ability to scatter light. Look at slide number thirty-three. The beam of light is visable as it passes through the suspension.

SLIDE SHOWS a smoke stack emitting smoke into the environment.

SLIDE #32

SLIDE SHOWS A 500ml beaker containing coffee. This is a demonstration of the Tyndall effect (shows a light beam passing through the colloidal suspension).

SLIDE #33

This scattering of light by a colloidal dispersion is called the

Tyndall Effect. It is sometimes used to measure concentrations of particles.

If the colloidal particles become so small that they are molecules of ions, the suspension becomes a solution. Solutions are dispersions of molecules or ions of one substance through another.

At this point, it might be well to ask what you need to know about this section of material. You will need to be able to recognize the definitions presented above, as well as instances in which the concepts are presented. Slide number thirty-four lists these terms.

Element - definition and characteristics
Symbol
Layout of the Periodic Chart (Table)
Metal
Nonmetal
Metaloid
Compound - definition and characteristics
Characteristics of: acids, bases, salts, organics
Neutralization
Suspensoid
Colloid
Tyndall Effect

SLIDE #34

In the next section we will consider a simplified model of the structure of matter. You will recall that matter cannot be divided into smaller and smaller parts indefinitely. When we get to a molecule, and divide it chemically, we have atoms. Atoms are what matter is made of. There are 92 naturally occurring species of atoms which we call elements.

Look at slide number thirty-five. An atom is the smallest particle of

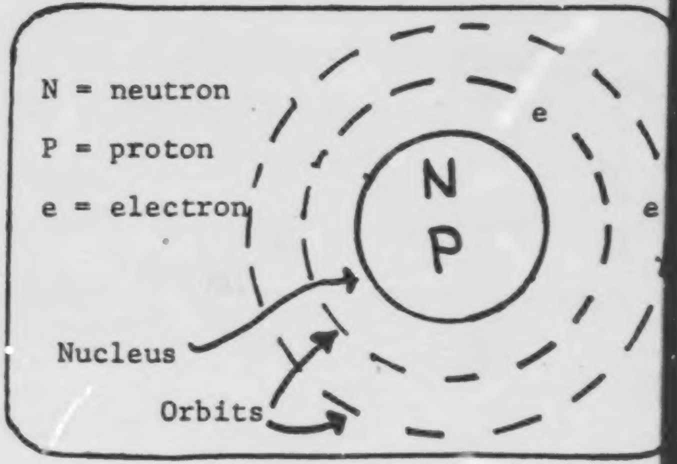
AN ATOM IS THE SMALLEST PARTICLE OF AN ELEMENT THAT CAN EXIST OR ENTER INTO COMBINATION WITH OTHER ATOMS.

Slide #35

an element that can exist separately or enter into combination with other atoms. All atoms of the same element are chemically alike.

Atoms can be broken down; however, not by chemical means. When they are broken down, all atoms are made up of 3 basic particles: electrons, protons and neutrons. Atoms of different elements simply contain different members of these basic particles.

Advance your slide carrousel to slide number thirty-six. It is thought that the basic particles are arranged in an atom as depicted in the diagram. Protons and neutrons comprise a heavy nucleus that is positively charged. The nucleus is very small; about one trillionth of a centimeter in diameter. Electrons are smaller and are about 10,000 radii out from the nucleus.



SLIDE #36

As an analogy, if the nucleus of an atom were the size of a basketball, the nearest electron would be about two miles away and somewhat smaller than a basketball. Atoms consist primarily of empty space with an incredibley dense nucleus; about a trillion times as dense as water.

If all the space were taken out of the atoms of the earth so that the protons, neutrons and electrons touched, it would be a sphere less than a mile in diameter.

Look at slide number thirty-seven. The normal set of weights and measures is not practical when working with atoms.

> Protons have a weight of 1 atomic mass unit, or amu and an electrical charge of +1
>
> Neutrons weigh 1 amu and have no charge
>
> Electrons weigh practically nothing and have a -1 charge

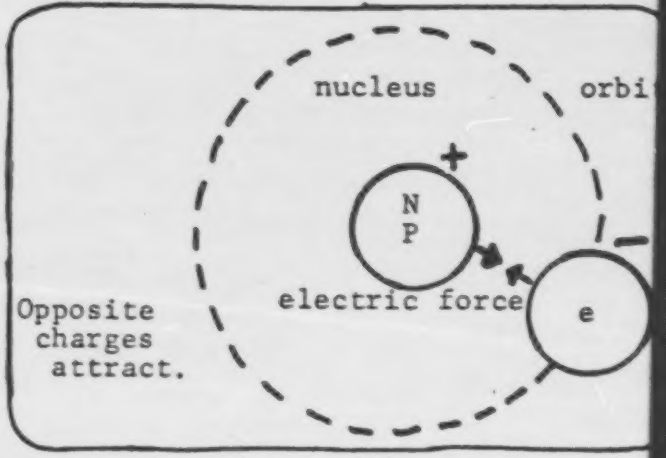
Proton: symbol = P or H^+
mass = 1 atomic mass unit (amu)
charge = +1

Neutron: symbol = N or n
mass = 1 amu
charge = 0

Electron: symbol = e
mass = 0
charge = -1

SLIDE #37

This difference in charge holds the atom together. Look at slide number thirty-eight. The motion of the electrons keeps them from falling into the nucleus, much as the earth's motion keeps it from falling into the sun.



SLIDE #38

What is the difference between the atoms of different elements? It is simply the numbers of protons and electrons. Look at slide number thirty-nine. Hydrogen has but one proton and one electron. Helium, the second element, has 2p, 2n and 2e. The third element, Lithium, has 3 protons, 3 electrons and 4 neutrons and so on.

The atomic number of an element is the number of protons in the nucleus. The atomic mass is equal to the sum of the number of protons and neutrons. Electrons have negligible mass.

Advance your carrousel to slide number forty. Notice that the atomic numbers are always whole numbers, while the weights are fractions. Does this mean that atoms can have fractions of neutrons in their nucleus? No, the reason the weights are fractions is that the number of neutrons in the atoms of elements may vary. For example, Hydrogen may have 0, 1 or 2 neutrons in its nucleus. Look at slide number forty-one. The type of hydrogen with no neutrons is the commonest. The other two types are heavy

See Page 23A -- Following

SLIDE #39

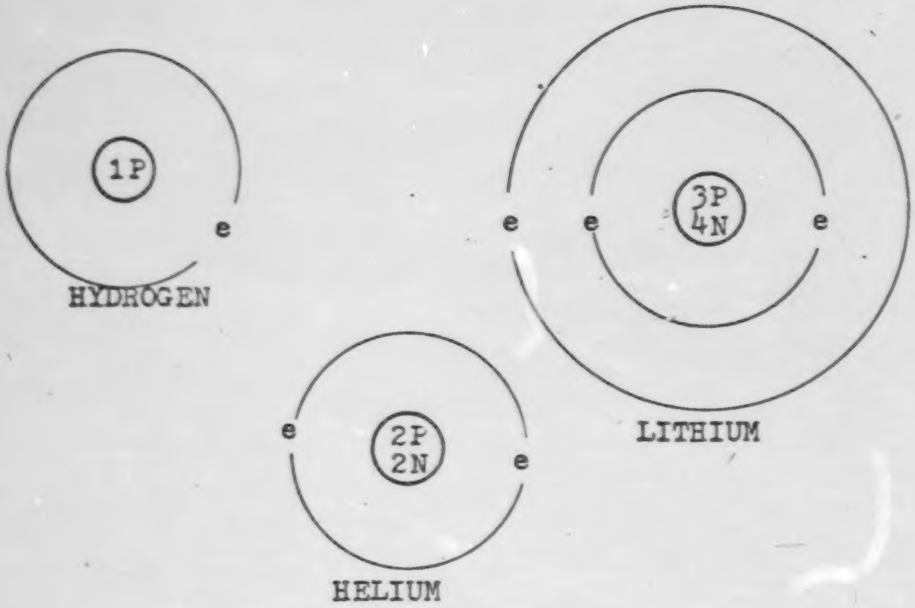
THE PERIODIC TABLE

SLIDE #40

See Page 23B -- Following

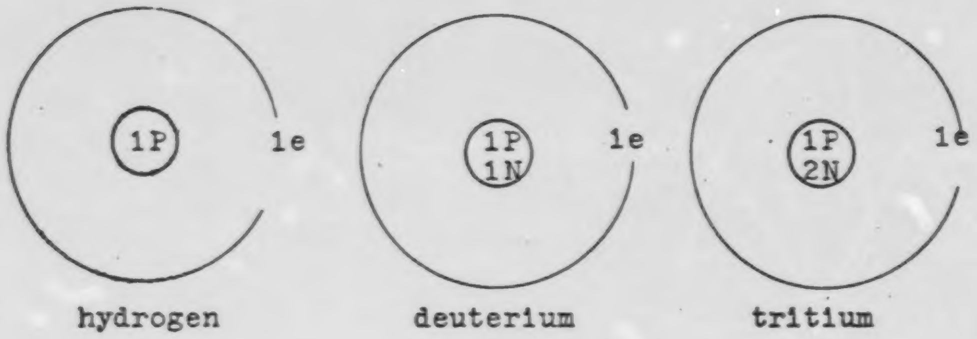
SLIDE #41

SLIDE #39


1P
e
HYDROGEN
e
e
3P
4N
e
LITHIUM
e
2P
2N
e
HELIUM

SLIDE #41

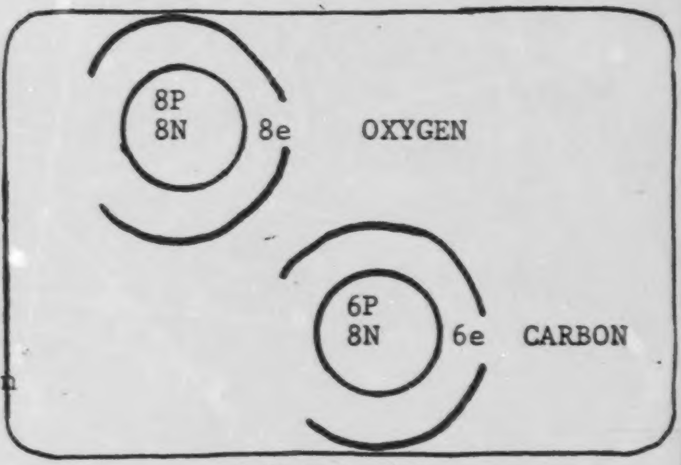
ISOTOPES OF HYDROGEN


1P
1e
hydrogen
1P
1N
1e
deuterium
1P
2N
1e
tritium

hydrogen. The different forms of hydrogen are called isotopes. The 3 isotopes of hydrogen then are hydrogen, deuterium and tritium.

Since all species of atoms have isotopes mixed together, their atomic weights are averages and therefore come out as fractions.

See if, on a piece of paper, you can draw a diagram of oxygen, atomic number 8 and atomic weight 16; and carbon, atomic number 6, atomic weight 14. You will be expected to draw or identify atoms if you are given their atomic weights and numbers.



SLIDE #42

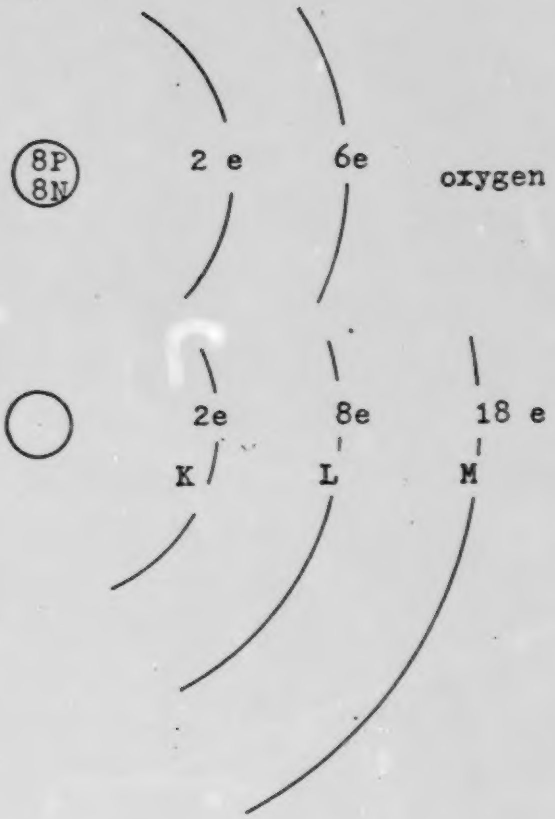
Look at slide number forty-two. Electrons are distributed about the nucleus in shells. Oxygen (O), for example, has two shells. It has two electrons in its innermost shell or level and six in its outermost shell. Shells have a limited capacity because electrons are all negative and therefore repel each other. Only so many can fit into a given space.

See Page 24A -- Following

SLIDE #43

Look at slide number forty-three. The shells are lettered by convention. The innermost shell is called

SLIDE #43


8P
8N
2 e
6e
oxygen
2e
8e
18 e
K
L
M

the K shell and the shells are alphabetically labeled from there. The capacities of the first three are given. You need not memorize them.

An atom of an element is electrically neutral, therefore the number of protons and the number of electrons are equal. If an atom gains or loses electrons it becomes charged and is then called an ion. Note on slide number forty-four. that the removal of 1 electron from a sodium atom leaves 11 protons and only 10 electrons, and therefore, a net charge of +1 on the resulting ion.

Now look at slide number forty-five. Chlorine has 17 protons, 18 neutrons and 17 electrons. If it gains 1 electron it becomes a chloride ion with a negative charge.

Generally, a gain of electrons produces negative ions while loss of electrons produces positive ions. Metals loose electrons; non-metals gain electrons. Hence, the difference between them.

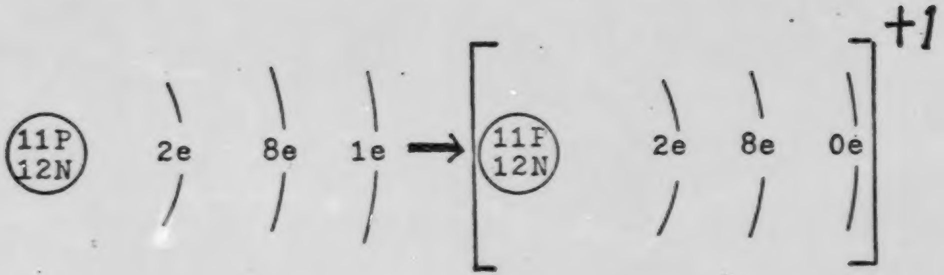
See Page 25A -- Following

SLIDE #44

See Page 25B -- Following

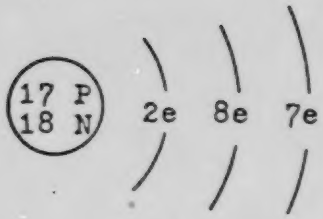
SLIDE #45

SLIDE #44

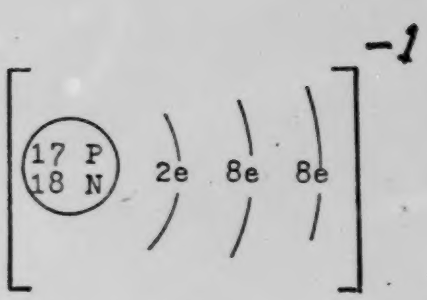

11P
12N
2e
8e
1e
11P
12N
2e
8e
0e
+1

SODIUM ATOM MINUS ONE ELECTRON YEILDS A SODIUM ION

SLIDE #45


17 P
18 N
2e
8e
7e

Chlorine Atom


17 P
18 N
2e
8e
8e
-1

Chlorine Ion

In chemical reactions, electrons are lost, gained or shared. There is never a change in the nucleus. All chemical reactions, from formations of rock to the growth of your body, are the result of changes in the electronic structure of atoms.

What will you need to know from this section? You will need to be able to recognize definitions of any of the concepts presented or examples of those concepts. You should be able to draw labeled diagrams of atoms. In addition, you should be able to calculate atomic mass, and be able to determine the number of protons and electrons from the periodic chart. Finally, you should be able to explain and illustrate the formation of ions.

In this section we will consider bonding, how the atoms in compounds are held together. Some of the basic ideas are outlined on slide number forty-six. Chemical reactions do not involve all the electrons of an atom, only the electrons in the

See Page 26A -- Following

SLIDE #46

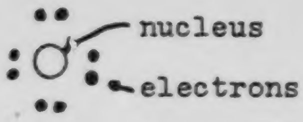
SLIDE #46

The electrons in the outermost shells of an atom are called VALENCE electrons

A valence shell is complete with 8 electrons

Shells with 8 electrons are stable: Those with less than 4 electrons tend to lose electrons, and result in metallic properties; those shells with more than 4 electrons tend to gain electrons, and result in properties we call nonmetallic.

STABLE:



outermost shell are called valence electrons. Valence electrons are involved in chemical change.

The most stable electron configuration for a valence shell is 8 electrons. The exception is the K shell which is so small that it is full with 2 electrons. Only 2 elements, hydrogen and helium, have the K shell as their valence shell.

Atoms tend to gain or lose electrons to fill or get rid of their valence shell. Those atoms with only a few electrons tend to lose while those with nearly 8 electrons tend to gain.

For example, sodium has only one electron in its valence shell. To complete that shell, it would have to gain 7 more electrons, giving the ion a charge of -7. It is easier to get rid of one electron and maintain a difference of +1 between the electron shells and the nucleus than it is to gain 7 electrons and maintain a -7 difference in charge. Conversely, it is easier for chlorine, which has 7 valence electrons, to gain one electron than to lose 7.

Atoms which tend to lose electrons have less than 4 valence electrons and are metals. The properties of metals, including luster, ductility, malleability, etc. are due to the ease with which they lose valence electrons.

Atoms which tend to gain electrons are non-metals and have more than 4 valence electrons.

Elements which have exactly 8 valence electrons tend to neither gain nor lose electrons and are therefore inert.

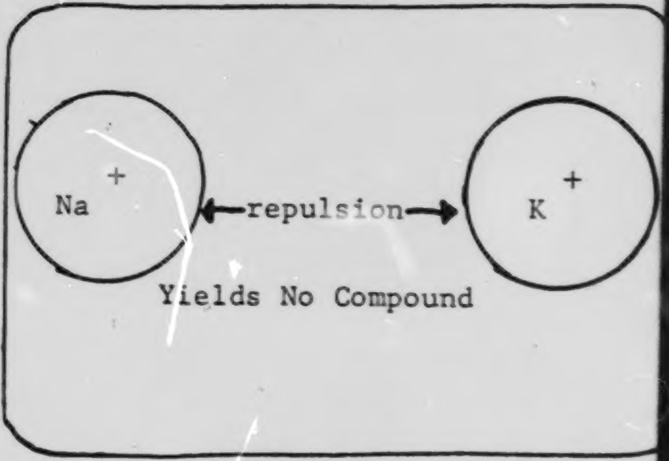
Those atoms with 4 electrons usually do not gain or lose, but rather share electrons.

Look at slide number forty-seven. Atoms which gain or lose electrons become ions. Ions are charged and, if their charges are opposite, they attract. Metals do not react with metals because they all form positive ions.

Advance your carrousel to slide number forty-eight. The ionic bonds that result from a combination of ions

See Page 28A -- Following

SLIDE #47

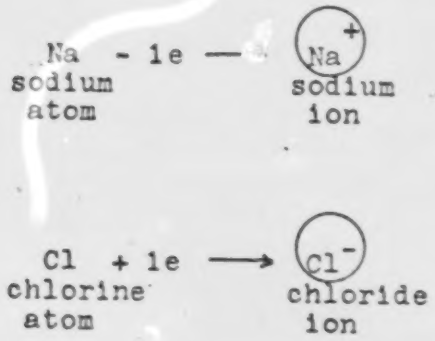


SLIDE #48

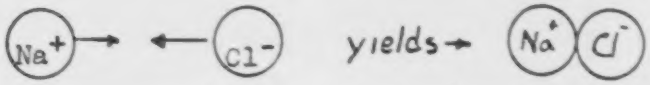
SLIDE #47

D1-47

Ionic bonding results when atoms, having gained or lost electrons, become charged and attract each other.


Na - 1e
sodium atom
Na +
sodium ion
Cl + 1e
chlorine atom
Cl -
chloride ion

Free ions attract, combine


Na +
Cl -
yields
Na +
Cl -

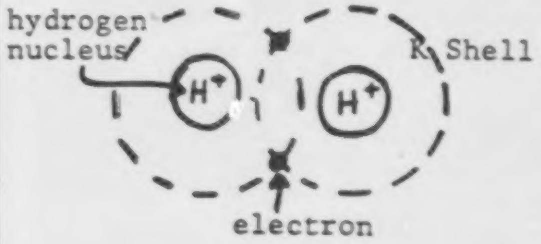
do not produce molecules, but instead crystals with no discernable molecules.

Advance your carrousel to slide number forty-nine. Slide number forty-nine depicts a salt crystal. There is nothing in this crystal that could be considered a molecule unless it is the whole crystal.

SLIDE SHOWS a picture of a cubic of NaCl showing the relative locations of Na^+ and Cl^-.

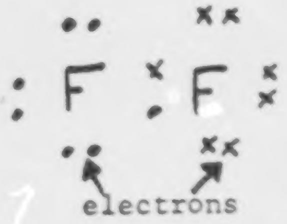
SLIDE #49

Look at slide number fifty. Atoms can sometimes more easily fill their shells by sharing electrons. A bond formed by sharing electrons is called a covalent bond. Notice that a difference in charges still holds the atoms together. The two positive hydrogen nuclei are drawn to the relatively negative area between them caused by the shared electrons.


HYDROGEN MOLECULE

SLIDE #50

Sharing electrons also completes the valence shell of each atom. Look at slide number fifty-one. Only valence electrons are shown, we ignore the others. The letter F represents the nucleus. The symbols of the electrons are as shown. Note that by sharing


FLUORINE MOLECULE

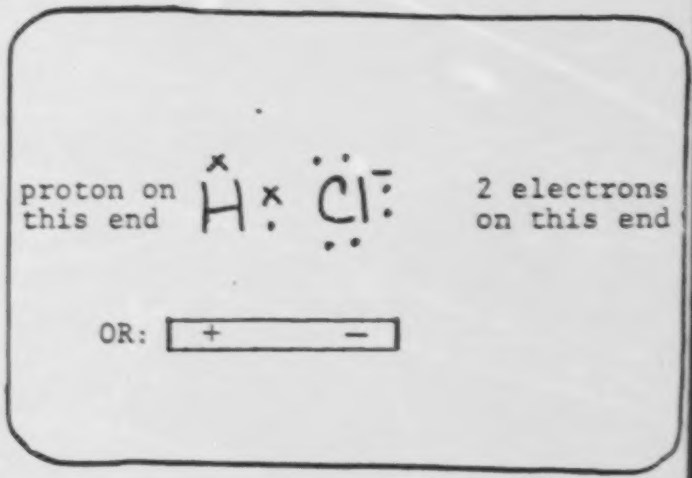
SLIDE #51

electrons, each atom can be surrounded by 8 valence electrons.

Look at slide number fifty-two. Covalently bonded molecules are quite often polar, that is, they have a small charge on each end. One end of the hydrogen chloride (HCl) molecule has a hydrogen (H) or proton sticking out. Protons, if you will recall, are positive. The other end has electrons sticking out and is, therefore, negative. The molecule has a positive and a negative pole and, therefore, is called a polar molecule.

Look at slide number fifty-three. Water molecules are not straight, but are bent. This makes them polar. Being polar, they tend to stick together and are hard to pull apart. This is why it takes so much energy to evaporate water.

Look at slide number fifty-four. Electrovalent bonds form when atoms gain or loose electrons. Covalent bonds form when atoms share electrons. The number of electrons shared completes the



proton on this end

2 electrons on this end

OR:

SLIDE #52

SLIDE SHOWS a picture showing the hydrogen bonding between several water molecules.

SLIDE #53

Electrovalent bond = ionic bond.

Particles which have gained or lost electrons (ions) form electrovalent bonds and result in ionic crystals.

Covalent bonds result from sharing electrons.

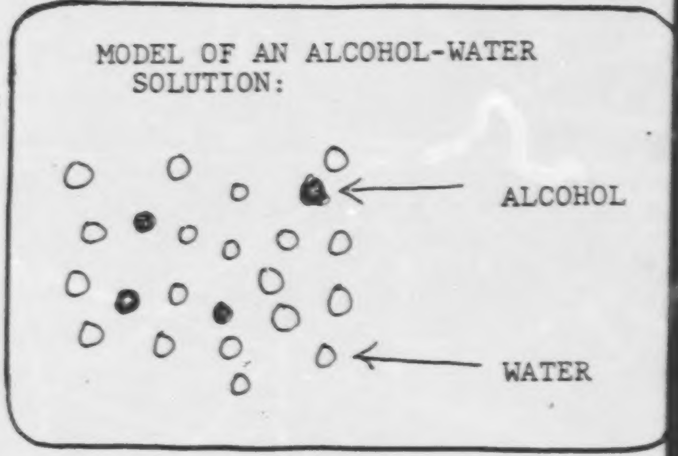
Covalent bonds result in molecules.

SLIDE #54

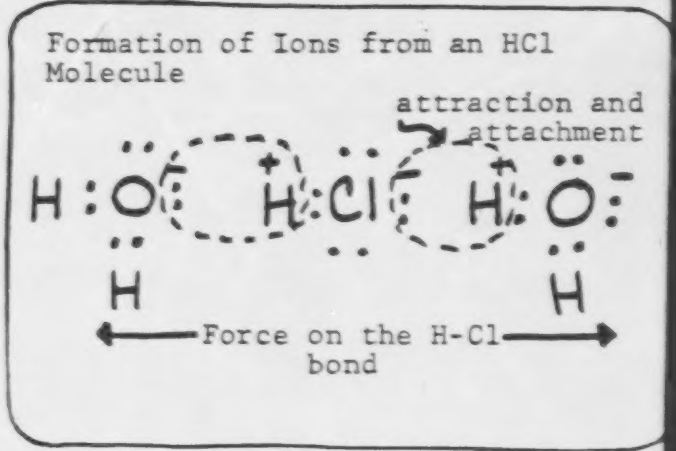
outer shell of each atom. Molecules are discrete neutral particles formed by covalently bonded atoms; ionic bonds, on the other hand, do not form molecules.

As a result of studying this section, you should recognize the concepts which were presented and be able to use these concepts in the explanation of chemical phenomenon.

Advance your carrousel to slide number fifty-five. Let's consider what happens when a material dissolves The simplest thing that can happen is that the molecules of solvent and solute just mix. When alcohol and water mix, or when oxygen dissolves in water, that is about what happens.


MODEL OF AN ALCOHOL-WATER SOLUTION:

SLIDE #55


Formation of Ions from an HCl Molecule

SLIDE #56

For most solutions, the picture is more complex. The best solvents, such as water (H_2O), are polar covalent materials. Look at slide number fifty-six. The polar nature of water helps it tear apart materials so that soluable ions form. Polar water molecules can pull apart a polar covalent molecule, such as hydrogen chloride (HCl) to yield a hydrogen ion (H+) and a chlorine ion (Cl-). The process is called ionization. Ionization is the production of ions from molecules.

Look at slide number fifty seven. In the case of ionic substances, a similar mechanism dissolves the solute. The surface ions, and particularly the corner ions of a crystal, are subject to attachment by a water molecule. As the molecules in the liquid vibrate and move, and the ions in the crystal vibrate, the water molecule often succeeds in pulling off an ion. As a result, the crystal dissolves. This process is called dissociation. Dissociation is the separation of ions from an ionic solid.

See Page 32A -- Following

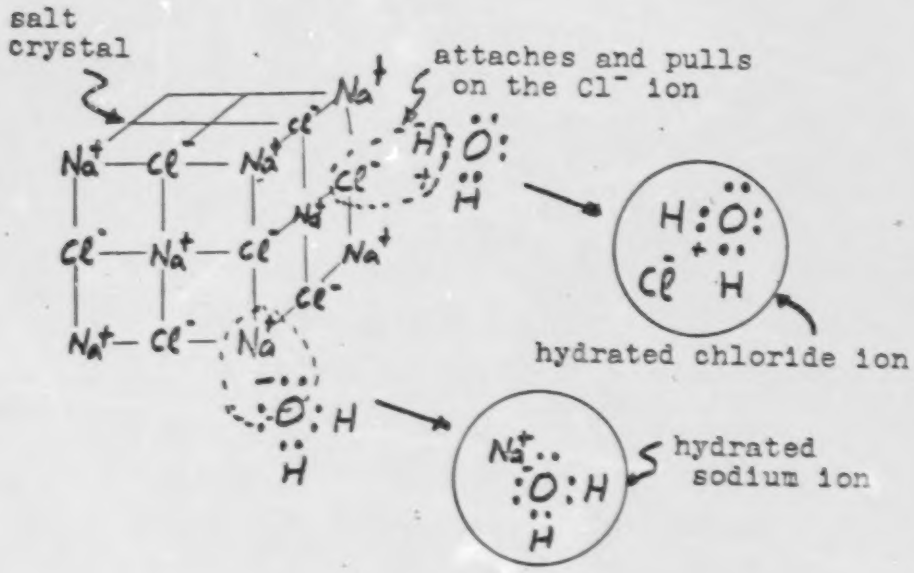
SLIDE #57

One might ask how do crystals form in solution. Crystals stop dissolving when enough ions are floating around in the solution so that the chance of an ion being pulled off equals the chance of it

SLIDE #57

DISSOCIATION OF AN IONIC MATERIAL

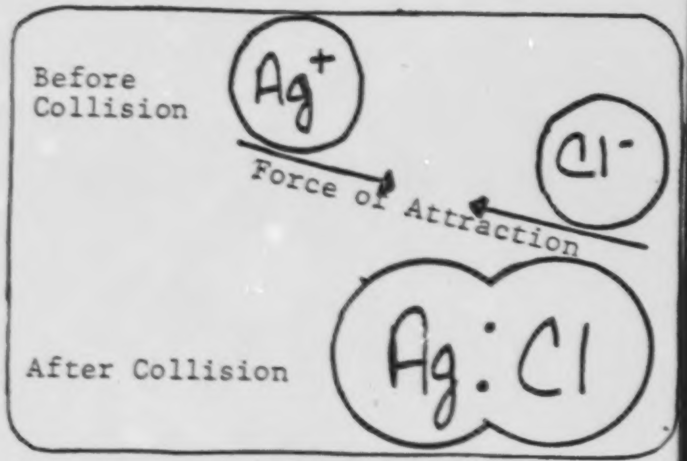
D1-57 Dissociation of an Ionic Material


salt crystal
attaches and pulls on the Cl⁻ ion
Na⁺
Cl⁻
H:Ö:
H
hydrated chloride ion
hydrated sodium ion
Na⁺
:Ö:H
H

being replaced. This point is called the saturation point.

Crystals form when the probability of an ion being replaced is greater than the probability of an ion being pulled off the crystal. This is why evaporation of a liquid, which increases the concentration of ions, causes dissolved salts to precipitate.

Look at slide number fifty-eight. Chemical reactions occur in solution if the result is removal of ions from solution. Ions in a solution move about at random and experience thousands of collisions per second. Sometimes, a pair of ions collide and form a bond strong enough so that the solvent doesn't pull them apart. On meeting a chloride ion (Cl), a silver ion (Ag) forms a stable molecule of silver chloride (AgCl). These molecules collect and form a visable white solid we call a precipitate. You might try this reaction by obtaining a small amount of sea water and adding a few drops of silver nitrate solution.



SLIDE #58

Advance to slide number fifty-nine. This particular reaction will be used in Unit D-2 to analyze for chloride ions in boiler water.

SLIDE SHOWS a bottle containing sea water, one containing $AgNO_3$, and a 125ml Erlenmeyer flack.

SLIDE #59

Reactions in solution will also occur if water is formed. The formation of water effectively removes hydrogen (H+) and hydroxide (OH-) ions.

What should you have learned from this last short section? You should be able to explain ionization and dissociation. In terms of what happens to ions, also you should be able to explain how crystals dissolve and how precipitates, or sludges, are formed.

Advance your carrousel to slide number sixty. The last section of this module will be concerned with formulas and equations.

A chemical symbol represents one atom of an element.

A formula represents the compositio of one molecule of a substance -- or the simplest ratio of atoms in an ionic substance.

SLIDE #60

A chemical symbol can be used to represent the name of an element, but in a formula the chemical symbol represents 1 atom of that element. A formula, made up of symbols, represents the makeup of one moleule, or in the case of an ionic substance, the symbol represents the simplest ratio of atoms. Subscripts indicate the number of atoms in the molecule.

Look at slide number sixty-one. Number 1 is the formula for water (H_2O). A molecule of water consists of 2 atoms of hydrogen (H) and one atom of oxygen (O). Number 2 is iron oxide (Fe_2O_3). A molecule of iron oxide contains 2 atoms of iron (Fe) and 3 atoms of oxygen (O).

1. H_2O
2. Fe_2O_3
3. $MgCO_3$
4. H_2SO_4

SLIDE #61

What are the contents of the molecules 3 and 4? Stop the tape a minute and figure it out.

Number 3 is magnesium carbonate ($MgCO_3$), a common scale formed in boilers. It contains one magnesium atom (Mg), 1 carbon (C), and 3 oxygen atoms (O).

Number 4 is sulfuric acid (H_2SO_4). It contains 2 hydrogens (H), 1 sulfur (S) and 4 oxygen atoms (O).

Advance your carrousel to slide number sixty-two. In molecules that have more than 2 kinds of atoms, the bond strength between different

$MgCO_3$ yields $Mg^{++} + CO_3^{=}$

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{=}$$

SLIDE #62

species of atoms is usually unequal. Slide number sixty-two shows what happens to the two molecules we were just working with when they break up.

Magnesium carbonate ($MgCO_3$) breaks between the Magnesium (Mg) and the carbon (C) rather than between carbon (C) and oxygen (O). Therefore, the two fragments that result on breakup are a Magnesium ion (Mg) and a carbonate ion (CO_3).

Groups of atoms that are bonded strongly enough to go through chemical reactions together are called radicals.

When something breaks up a sulfuric acid molecule (H_2SO_4), the hydrogens (H) break off easiest. The 3 resulting fragments are 2 hydrogen ions plus a sulfate radical (SO_4). The sulfate radical is charged so that it is also an ion.

Look at slide number sixty-three. Some other radicals frequently associated with boiler water treatment are listed. You might take a minute to read through them.

SOME OTHER RADICALS:

CrO_4^{-2}	chromate	SiO_3^{-2}	silicate
NO_3^{-1}	nitrate	PO_4^{-3}	phosphate
NO_2^{-1}	nitrite	HCO_3^{-1}	bicarbonate
SO_3^{-2}	sulfite	NH_4^{+1}	ammonium
OH^{-1}	hydroxide		

SLIDE #63

You should be familiar with them but you need not memorize them.

Advance to slide number sixty-four. A chemical equation consists of formulas which indicate the reactants and products of a reaction.

Look at slide number sixty-five. It is convention to write the formulas for the materials that react on the left side and the results of the reaction, or products, on the right side. The coefficients in front of formulas indicate the number of molecules involved in the reaction.

The first reaction says that 2 molecules of hydrogen (H) gas, each containing 2 atoms of hydrogen (H) react with one molecule of oxygen (O), containing 2 atoms, to yield 2 molecules of water ($2H_2O$), each containing 2 atoms of hydrogen (H) and one of oxygen (O).

The second reaction says that one atom of zinc (Zn) containing 1 atom per molecule, reacts with 2 molecules of hydrogen chloride (HCl) to yield one molecule of zinc

A chemical equation gives an overall description of a chemical reaction. It consists of formulas which indicate the materials going into the reaction (REACTANTS) and the materials coming out of the reaction (PRODUCTS).

$$\text{REACTANTS} \xrightarrow{\text{yield}} \text{PRODUCTS}$$

$$A + B + C + \cdots \longrightarrow X + Y + \cdots$$

$$2H_2 + O_2 \longrightarrow 2H_2O$$

SLIDE #64

1. $2\,H_2 + O_2 \longrightarrow 2H_2O$
2. $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$
3. $2Ag^+ + CaCl_2 \longrightarrow 2AgCl + Ca^{++}$

Ag^+ = SILVER ION

$CaCl_2$ = CALCIUM CHLORIDE

Ca^{++} = CALCIUM ION

AgCl = SILVER CHLORIDE

SLIDE #65

chloride ($ZnCl$) plus one molecule of hydrogen (H).

Reaction number three says that two silver (Ag) ions react with 1 calcium chloride ($CaCl$) molecule to yield 2 silver chloride ($AgCl$) molecules and a calcium (Ca) ion.

As a result of studying this section you should be able to recognize definitions of the terms symbol, formula, radical and equation. You should be able to interpret these definitions.

This is the end of Module D1. Look at slide number sixty-six. It contains the technical vocabulary used in the module. You may review these definitions by going back through the module or you might consult some standard introductory chemistry text.

See Page 38A - Following

SLIDE #66

Once you have learned the vocabulary and understand the basic ideas, you will be ready to take the D1 end of module test. If your test results are not at or above the minimum competency level, you will be required to retake the test.

PHASE
DENSITY
SOLUBILITY
LUSTER
DUCTILITY
MALLEABILITY
TENACITY
BRITTLENESS
HOMOGENEOUS
MOLECULE
SOLVENT
SOLUTE
SOLUBILITY
ELEMENT
SYMBOL
ACID
BASE
SALT
INDICATOR
NEUTRALIZATION

ORGANIC COMPOUNDS
COLLOID
SUSPENSION
TYNDALL EFFECT
ATOM
ELECTRON
PROTON
NEUTRON
ISOTOPE
ION
ELECTROVALENT BOND
IONIC BOND
COVALENT BOND
IONIZATION
DISSOCIATION
PRECIPITATION
FORMULA
EQUATION
RADICAL

SLIDE #66

MODULE D-1 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G. H., and Augustine, F. B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed with a grade of 70% prior to taking the MODULE D-1 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE D-1 as well as to the completion of the problem set. Those pages are 4, 11, 12, 22, 28-41, 45-56, 59, 60, 65, 79, 83, 84, 105-113, 139-147, 151-164, 170-180, 184, 185, 190-192, 196, 197, 200, 203-206, 216, 222-230, 239, 276-278.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown. (Read across)

PAGE	PROBLEMS
24	7, 8, 9, 10
42	B-6, 7, 10, 11
55	5, 10, 11
117	1
148	1
165	B-7
180	B-1
219	4
280	2

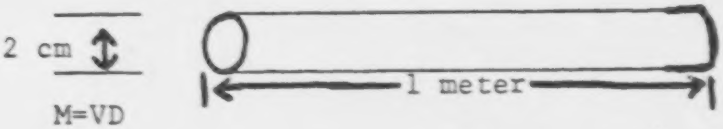
MODULE D-1 PROBLEM SET SOLUTIONS

PAGE PROBLEM

24 (7)

$D = M/V$
$V = 13\ ml$
$M = 252.55g = 75.35g$
$= 177.20g$
$D = 177.20g/13\ ml$
$= 13.6\ ml$

24 (8)



$M=VD$

$V = \pi r^2 l$ $D = 1.74g/ml$
$= 3.14 \times 1^2 \times 100cm$
$= 314\ cc$

$M = 314ml \times 1.74g/ml$
$= 546.36g$

24 (9)

$D\ ALUMINUM = 2.70\ g/ml$
$V = 314\ ml$
$M = DV$
$= 314\ ml \times 2.70\ g/ml$
$= 847.8g$

$$\frac{D\ ALUMINUM}{D\ MAGNESIUM} = \frac{847.8g}{546.36g}$$

Aluminum is 1.55 times heavier.

24 (10)

$D = M/V$
$D = 90mg/l$
$= .09g/l$

42 (B6)

Atoms in 40.08g = 6.02×10^{23} atoms
Atoms in 1g Ca = $\frac{6.02 \times 10^{23}}{40.08}$

Atoms in 300g Ca = Atoms in 1g Ca x 300 = 4.50×10^{24} atom

42 (B7)

$74.92g$ As = 6.02×10^{23} Atoms
1 Atom As = $\frac{6.02 \times 10^{23}}{74.92}$

$= 1.24 \times 10^{-22}$g/As Atom

PAGE PROBLEM

42 (B10) 1 Mole Ni = 58.71g

? Moles in 500g Ni $= \frac{500}{58.71}$

= 8.50 moles/500g

42 (B11) 1 Mole U = 238.03g
5 Moles U 238.03g x 5
= 1190g U

55 (5) 1 Mole ZnS = 65.38g + 32.064g
= 97.444g
3 Moles ZnS = 97.444g x 3
= 292g

1 Mole C_4H_8 = (12.01g x 4) + (1g x 8)
= 48.04g + 8g
= 56.12g
3 Moles C_4H_8 = 56.12g x 3
= 168.36g

1 Mole MnO_2 = 54.938g + (15.999g x 2)
= 86.938g
3 Mole MnO_2 = 86.938g x 3
= 260.81

1 Mole CaC_2 = 40.08g + (12.01g x 2)
= 64.10g
3 Mole CaC_2 = 64.10g x 3
= 192.30g

1 Mole $CaCO_3$ = 40.08g + 12.01g + (15.999g x 3)
= 100.09g
3 Mole $CaCO_3$ = 100.09g x 3
= 300.27g

55 (10)

NH_3	17.0 amu	17.0g	5.88 moles	5.88 moles
N_2H_4	32.0 amu	32.0g	3.12 moles	6.24 moles
NH_2OH	33.0 amu	33.0g	3.03 moles	3.03 moles

55 (11)

NH_3	2.94×10^{-2}	1.77×10^{22}	8.82×10^{-2}	5.31×10^{24}
N_2H_2	1.56×10^{-2}	9.41×10^{21}	6.24×10^{-2}	3.76×10^{22}
NH_2OH	1.52×10^{-2}	9.12×10^{21}	27.4×10^{-2}	2.74×10^{22}

PAGE PROBLEM

117 (1)

Pure water has the higher surface tension. The addition of soluble substances to pure water lowers the surface tension.

148 (1)

Nucleus	$^{19}_{9}F$	$^{40}_{20}Ca$	$^{56}_{26}Fe$	$^{54}_{26}Fe$	$^{57}_{26}Fe$	$^{252}_{99}Es$
Protons	9	20	26	26	26	99
Neutrons	10	20	30	28	31	153
Mass Number	19	40	56	54	57	252

165 (B7)

Cr

180 (B1)

Ga	Gallium	31	IIIA	3
Ge	Germanium	32	IVA	4
As	Arsenic	33	VA	5
Se	Selenium	34	VIA	6
Br	Bromine	35	VIIA	7
Kr	Krypton	36	NOBLE GAS	8
Rb	Rubidium	37	IA	1
Sr	Strontium	38	IIA	2
In	Indium	49	IIIA	3
Sn	Tin	50	IVA	4
Sb	Antimony	51	VA	5
Te	Tellurium	52	VIA	6
I	Iodine	53	VIIA	7
Xe	Xenon	54	NOBLE GAS	8
Ce	Cesium	55	IA	1
Ba	Borium	56	IIA	2

219 (4)

a) 6.0M, 0.150g moles; b) 5.71M, 0.111g; c) 222 ml, 35.0g; d) 1.26 ml, 3.79×10^{-3} mole.

280 (2)

As temperature ↑ molecular activity ↑. An increase in molecular activity increases rate at which reactants will come in contact with one another. The more rapidly they come in contact with one another, the greater will be the reaction rate.

NAME ______________________

MODULE D1 - 1 EXAMINATION

1. Define each of the following:
   - a. Density
   - b. Solution
   - c. Solvent
   - d. Element
   - e. Acid
   - f. Neutralization
   - g. Organic Compound
   - h. Atom
   - i. Isotope
   - j. Ion
   - k. Ionic Bond

2. Draw a sketch of the Periodic Table giving the location of metals, nonmetals and inert gases.

3. Draw a simplified model of the carbon atom. Carbon = At. Wt. 12 and At. #6.

P.44

MODULE D1-1 EXAMINATION SOLUTION SET

1. a. The ratio of mass to volume. D = M/V.

   b. A homogeneous mixture.

   c. The medium in which the solute is dissolved; the component of a solution present in the greatest amount.

   d. One of the 106 known building blocks of matter.

   e. A substance that can give up a proton; a proton donor; any substance containing hydrogen which when added a solvent increases the H^+ concentrations.

   f. The reaction of an acid and a base. The combination of H_3O^+ and OH^- ions to form water and a salt.

   g. The study of chemical compounds containing carbon.

   h. Elements of a substance which retain the properties of a substance.

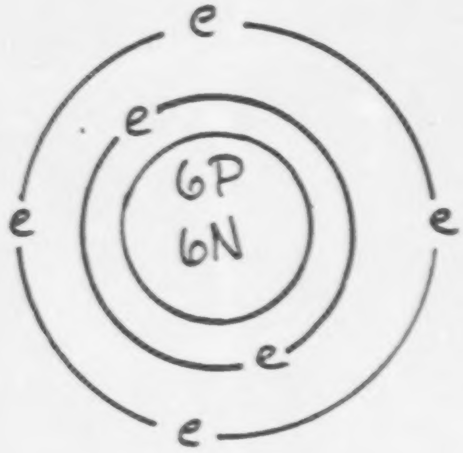
   i. Atoms of the same element which have different masses.

   j. A charged atom or molecule.

   k. An electrovalent bond. A bond which is formed when the electron(s) of one participant are given to the other.

2. See Periodic Table. (P. 44A)

3.



MODULE DI-1 EXAMINATION SOLUTION SET
P. 44A
#2

Periodic Chart of the Elements

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	NOBLE GASES
1 H 1.0079																1 H 1.0079	2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.81	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.99840	10 Ne 20.179
11 Na 22.98977	12 Mg 24.305											13 Al 26.98154	14 Si 28.086	15 P 30.97376	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.9559	22 Ti 47.90	23 V 50.9414	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.22	41 Nb 92.9064	42 Mo 95.94	43 Tc 98.9062	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.4	47 Ag 107.868	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.9045	54 Xe 131.30
55 Cs 132.9054	56 Ba 137.34	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.9665	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.9804	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	89 Ac (227)	104 § (260)	105 § (260)													

58 Ce 140.12	59 Pr 140.9077	60 Nd 144.24	61 Pm (147)	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.50	67 Ho 164.9304	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.97
90 Th 232.0381	91 Pa 231.0359	92 U 238.029	93 Np 237.0482	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (255)	103 Lr (256)

NAME ______________________________

MODULE D1 - 2 EXAMINATION

1. Give two examples of elements.

2. Give two examples of mixtures.

3. Give two examples of compounds.

4. Give two examples of suspension.

5. Make a rough sketch of the Periodic Table and show the location of the METALS, NON-METALS, METALOIDS, INERT GASES.

6. Flourine (F) has an atomic number of 9 and an atomic weight of 19.

   a. How many protons does it have? __________

   b. How many neutrons does it have? __________

   c. How many electrons are there in the neutral atom? __________

7. There is only one thing which really distinguishes an atom of one element from another atom of another element. It is the number of

   ____________________________.

8. An ion of an element is an atom of that element which has

   ______________________________.

9. An isotope of an element is an atom of that element which has

   ______________________________.

10. Draw a diagram of an atom of Sodium (Na), which has an atomic number of 11 and an atomic mass of 22.99 and show the electrons in each of the shells.

MODULE D1 - 2 EXAMINATION SOLUTION SET

1. Hydrogen, carbon.

2. Two or more substances each with their characteristic properties.

3. A substance whose molecules are composed of more than one kind of atom.

4. Particles distributed in a solvent. The solvent and properties maintain their respective identities.

5. See the Periodic Table with D1-1 Solution Set. (P. 44A)

6. a. 9

   b. 10

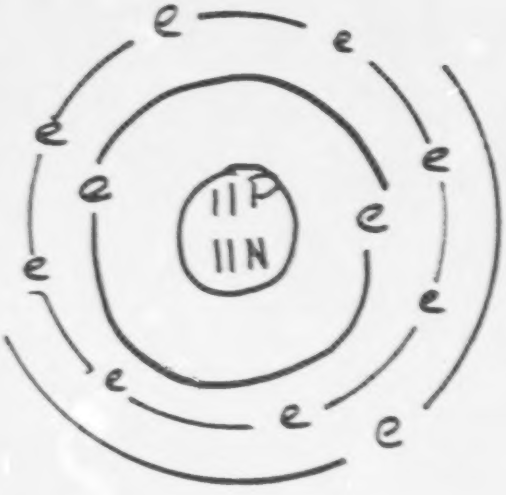
   c. 9

7. Atomic number.

8. An excess of a deficiency of electrons.

9. Atoms which have the same atomic number but different numbers of neutrons in their nucleus.

10.



Name ____________________

MODULE D1 - 3 EXAMINATION

1. I have an atom of oxygen. The atomic weight is 17 and the atomic number is 8.

   a. How many electrons does it have? ________

   b. How many protons does it have? ________

   c. How many neutrons does it have? ________

   d. How many electrons does it need to fill up its outer shell?

   ____

2. Sketch the Periodic Table and show the location of the metals, nonmetals, metaloids and noble gases.

3. Is brass a mixture or a compound? Explain your answer.

4. What is the difference between a true solution (e.g. salt water) and a suspension (e.g. muddy water)?

5. When an acid and a base neutralize, what are the products?

   ________________ and ________________

6. What is it about inert gases (noble gases) that makes them inert (unable to react with anything else)?

7. Name the two types of chemical bonding and explain the difference.

   a. ________________bond, electrons are ________________

   b. ________________bond, electrons are ________________

MODULE D1 - 3 EXAMINATION SOLUTION SET

1. a. 8

   b. 8

   c. 9

   d. 2

2. See the Periodic Table with D1 - 1 examination solution set. (P. 44A)

3. Brass is a solid solution of copper and zinc. (Compound is a pure substance composed of one or more kinds of atoms.)

4. The constituents can not be separated by mechanical means.

5. Salt + H_2O.

6. Their outer shell holds all of the electrons it possibly can.

7. a. Ionic ---- One of the participants gives up while the other takes one or more electrons.

   b. Covalent ---- Electrons are shared between participants of the bond.

Name______________________________

MODULE D1 - 4 EXAMINATION

1. An object has a volume of 35 cubic centimeters and a mass of 17.5 grams. What is its density? ______________________________

2. Diagram an atom having three protons, two neutrons, and three electrons.

3. Define the following:

   a. Solvent

   b. Solute

   c. Solubility

   d. Salt

   e. Phase of matter

   f. Ion

   g. Electron

4. What are the products of an acid - base neutralization?

5. Describe the construction of the Periodic Table. In your discussion include the reasons why an element is placed in one spot and not another.

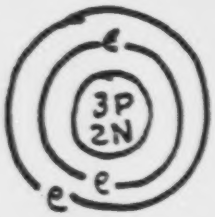
MODULE D1 - 4 EXAMINATION SOLUTION SET

1. $D = M/V$

   $= 17.5g/35cc$

   $= \frac{1}{2}\ g/cc$

2.



3. a. The medium in which the solute is dissolved; the component of the solution present in the greatest amount.

   b. The component of a solution present in amounts less than that of the solvent, the dissolved substance.

   c. The ability of a compound to dissolve in a solution.

   d. A compound in which the H ions of an acid have been replaced by metal ions or ammonium ions.

   e. Solid, liquid, gas.

   f. An atom which has an excess or a deficiency of electrons.

   g. A subatomic particle having a charge of -11 or 1.60×10^{-19} coulombs.

4. Salt + H_2O.

5. See Periodic Table in D1-1 examination solution set. The properties of the elements are a periodic function of their atomic numbers. (P.44A)

Name______________________________

MODULE D1 - 5 EXAMINATION

1. Aluminum has a density of 2.70 g/ml. What is the mass of a rectangular block 10 cm x 100 mm x 10^{-1} M?

2. Describe what happens as the energy of molecules increases.

3. Sketch a picture of the Periodic Table. Describe its construction and the factors determining the placement of the elements.

4. Define each of the following:

   a. Radical

   b. Equation

   c. Formula

   d. Precipitation

   e. Dissociation

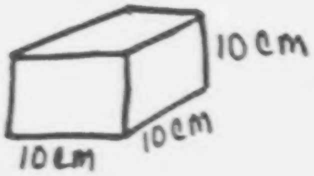
   f. Covalent Bond

   g. Neutron

   h. Ion

MODULE D1 - 5 EXAMINATION SOLUTION SET

1.



$V = 1000$ cc
$D = M/V$
$M = DV$
$= 2.70\text{g/cc} \times 1000$ cc
$= 2700\text{g}$

2. Movement becomes more rapid and eventually they break away from the structure in which they exist. Here a change in state occurs (solid, liquid, gas).

3. See the Periodic Table in Module D1-1 examination solution set, and Number 5 in D1-4 examination solution set.(P. 44A and P. 50)

4. a. A group of two or more atoms that acts as a single atom and goes through a reaction unchanged or is replaced by a single atom.

   b. A statement of a chemical reaction using formula notation.

   c. The chemical notation of a compound.

   d. The settling out of a solid material from a solution.

   e. The separating of atoms which were united by some type of chemical bond.

   f. A bond between atoms in which electron pairs are shared by two atoms.

   g. An uncharged subatomic particle having an atomic mass of 1.008 amu.

   h. An atom having an excess or a deficiency of electrons.

Name_________________________________

MODULE D1 - 6 EXAMINATION

1. Define each of the following:
   a. Colloid

   b. Neutralization

   c. Charge

   d. Ionic Bond

   e. Isotope

   f. Proton

2. Draw a picture of the Periodic Table, showing the placement of inert gases, metals, etc.

3. Explain the reasons for the placement of elements in their respective places on the Periodic Table.

4. If atoms gain or loose electrons in the bonding process, what type of bond is formed?

5. How many atoms are in 100g of copper? The atomic mass of copper is 63.54.

6. How is density related to mass and volume?

MODULE D1-6 EXAMINATION SOLUTION SET

1. a. Particles, larger than molecules but small enough to remain suspended in solution.

   b. The reaction of an acid with a base. In an aqueous solution the reaction involves H_3O^+ with OH^- ions to form H_2O and a salt.

   c. An excess or a deficiency of electrons.

   d. A bond which is formed when the electron(s) of one participant are given to the other.

   e. Atoms of the same element that have different masses.

   f. A subatomic particle having a charge of +1 and a mass of 1.

2. See the Periodic Table in Module D1-1 examination solution set. (P. 44A)

3. See Number 5 in D1-4 examination solution set. (P. 50)

4. Ionic

5. 1 mole of copper = 63.54 grams

   $6.02\text{x } 10^{23}$ atoms = 1 mole

   $$\frac{63.54\text{g Cu}}{6.02 \times 10^{23}\text{ atoms}} = \frac{100\text{g Cu}}{X}$$

   $63.54X = 6.02 \times 10^{25}$ atoms

   $X = 9.4514 \times 10^{23}$ atoms.

6. D = M/V

Name_______________________

MODULE D1 - 7 EXAMINATION

1. When in chemistry are salt and water formed?

2. Lead has a density of 11,34g/cc. What is the mass of a rectangular block 10cm x 100mm x 10^{-1}M?

3. Draw a diagram of an atom of magnesium, which has an atomic number of 12 and an atomic mass of 24.3. Show the electrons in each of the shells.

4. Define each of the following:

   a. Organic compounds

   b. Homogeneous

   c. Indicator

   d. Electrovalent bond

   e. Dissociation

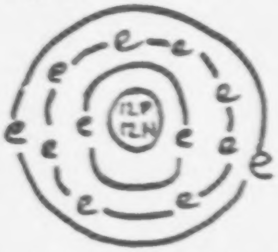
5. Sketch the Periodic Table, showing the placement of inert gases, metals, etc. Discuss the reasons why elements are placed where they are on the table.

MODULE D1 - 7 EXAMINATION SOLUTION SET

1. In acid - base neutralization.

2. M = 11.34g/cc x 1000cc = 11340g.

3.



4. a. Carbon containing compounds.

   b. Similar properties throughout.

   c. A substance that exhibits different colors depending on the acidity or basicity of the solution.

   d. An ionic bond, the type of bond which results from the attraction of positive and negative ions.

   e. The coming apart of atoms through the breakage of the bonds between the atoms.

5. See the Periodic Table in D1-1 examination solution set and number 5 in D1-4 examination solution set. (P. 44A and P. 50)

P.57

Name____________________

MODULE D1 - 8 EXAMINATION

1. How is an atom of an element represented?

2. How is the mass of an atom determined?

3. The Periodic Table contains a group of elements called the inert gases. Discuss the characteristics peculiar to these gases.

4. Sketch the Periodic Table showing the placement of metals, nonmetals, inert gases, etc. Discuss the reasons why these groups are placed where they are.

5. An atom of oxygen has an atomic mass of 15.99 and an atomic number of 8. Make a sketch of that atom showing numbers of protons, neutrons and electrons and their placement.

6. Define each of the following terms:

   a. Solute

   b. Solid

   c. Density

   d. Evaporation

   e. Homogeneous

   f. Colloid

MODULE D1 - 8 EXAMINATION SOLUTION SET

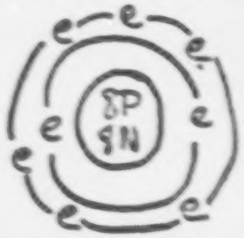
1. By its atomic symbol.

2. By adding the mass of its neutrons and protons.

3. Inert gases have complete outer rings.

4. See the Periodic Table with Module D1-1 examination solution set and Number 5 of D1-4 examination solution set. (P. 44A and P. 50)

5.



6. a. The component of a solution present in amounts less than that of the solvent, the dissolved substance.

   b. A state of matter in which the particles have definite positions and the object has a definite shape.

   c. Mass divided by volume, the quantity of matter per unit volume.

   d. Vaporization, the change from the liquid to the gaseous state.

   e. The same throughout.

   f. Particles larger than molecules but small enough to remain suspended in a fluid medium.

Name ______________________________

MODULE D1 - 9 EXAMINATION

1. The atomic mass of gold is 196.967. How many atoms of gold are contained in 300g of gold?

2. 500 ml of chlorine gas at 0° C and 1 atmosphere has a mass of 50 mg. What is the density of the gas in grams per liter at conditions of standard temperature and pressure?

3. Define each of the following:

   a. Density

   b. Acid

   c. Malleability

   d. Neutron

   e. Ionic bond

   f. Formula

   g. Mixture

   h. Periodic table

   i. Organic chemistry

   j. Elements

   k. Electrons

   l. Atoms

   m. Neutralization

4. What are the products of an acid-base neutralization?

MODULE D1 - 9 EXAMINATION SOLUTION SET

1. 1 mole gold = 196.976g 1 mole = 6.02×10^{23} atoms

$$\frac{196.976\ g}{6.02 \times 10^{23}\ \text{atoms}} = \frac{300\ g}{X}$$

$196.976\ X = 300 \times 6.02 \times 10^{23}$ atoms

$X = 9.24 \times 10^{23}$ atoms

2. 500 ml = .5 l D = M/V

50 mg = .05 g STP = 0° C at 1 ATM

$D = \frac{.05\ g}{.5\ l} = \frac{2}{2} \times .10\ g/l$

3. a. The ratio of mass to volume. D = M/V.

b. A substance which can give up a proton, a proton doner. In aqueous solutions, acids increase H_3O^+ concentration.

c. Can be hammered into sheets.

d. An uncharged atomic particle having a mass of 1.

e. A chemical bond in which electrons are transferred from one atom to another.

f. A group of chemical symbols which represent some compound.

g. A combination of two or more substances, each with its own characteristic properties.

h. A table which systematically lists the elements.

i. The chemistry of carbon compounds.

j. One of the 106 building blocks of matter. The smallest division of matter which allows identification of specific atoms.

k. A subatomic particle which has a charge of -1 or 6.242×10^{-19} coulombs and esentially zero mass.

l. The smallest particles which retain the properties of a substance.

m. The reaction of an acid with a base. In an aqueous solution the reaction involves H_3O^+ with OH^- ions to form H_2O and a salt.

4. Salt + H_2O.

Name ______________________________

MODULE D1 - 10 EXAMINATION

1. Calculate the density of ether if the mass of the empty container = 170.0 g and the mass of the container plus 30.0 ml ether = 193.7 g.

2. How many atoms are there in 5 moles of oxygen if the atomic mass of oxygen is 15.9994?

3. Sketch the Periodic Table, showing the placement of metals, non-metals, inert gases, etc. Also describe what determines the placement of the various elements.

4. Define each of the following terms:

   a. Salt

   b. Symbol

   c. Formula

   d. Density

   e. Indicator

5. Give two examples of mixtures.

6. Draw a sketch of an atom of flourine (F), atom mass = 18.99840 and atomic number = 9 .

MODULE D1 - 10 EXAMINATION SOLUTION SET

1. 193.7g - 170.0g = 23.7g

   D = M/V   V = 30.0 ml

   D = 23.7g/30ml

   = .79g/ml

2. 1 mole oxygen = 15.9994g

   1 mole = 6.02×10^{23} atoms

   5 moles oxygen = $5 \times 6.02 \times 10^{23}$ atoms

   = 30.10×10^{23} atoms

3. See Module D1-1 examination solution set, and Number 5 of Module D1-5 examination solution set. (P. 44A and P. 52)

4. a. A compound in which the H ions of an acid have been replaced by metal ions or ammonium ions.

   b. Letters and letter combinations which represent the elements.

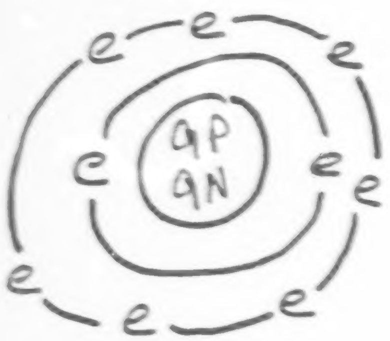
   c. The combination of of letter symbols which represent the chemical union of elements.

   d. The ratio of mass to volume, D = M/V

   e. A substance that exhibits different colors depending on the acidity of basicity of a solution.

5. A combination of two or more substances each with its own characteristic properties.

6.



MODULE D-2 BASIC BOILER WATER TESTS

Module D-2, Basic Boiler Water Tests, is the second module you will study as you proceed through the course. This module introduces the student to some basic boiler water tests. However, the tests with which one works in this module are by no means all of the boiler water tests which can be made on boiler water.

The primary objective of the boiler water analysis tests will be ion analysis. That is, water samples will be analyzed to ascertain whether they contain ions and if so, what the ions are. This task generally is accomplished by analyzing small samples of boiler water.

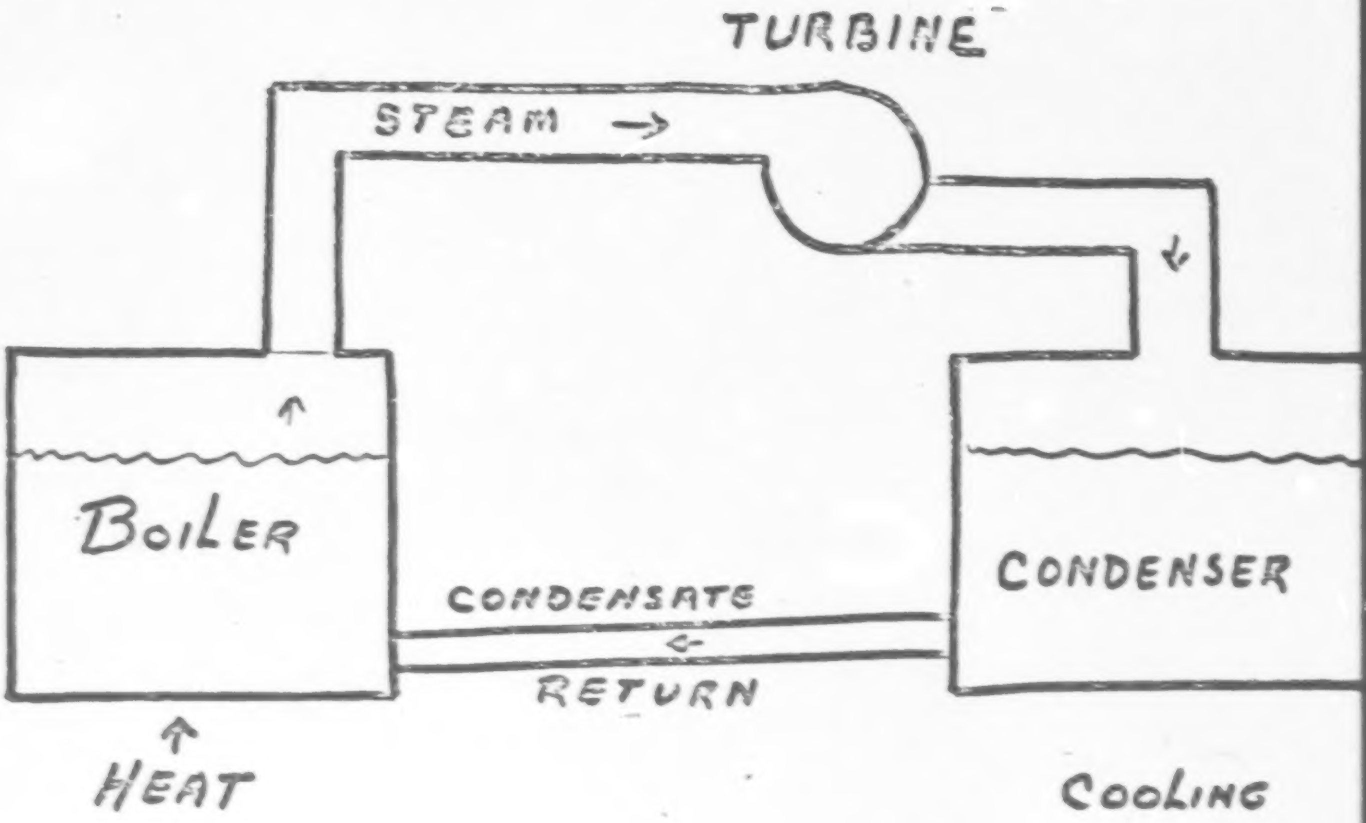
The marine engineer has, among his many duties, the responsibility of efficient operation of the steam generating plant. The heart of this system is the boiler.

Advance your slide carrousel to slide number one. A boiler is simply a closed container where

SEE PAGE 63A --- FOLLOWING

SLIDE #1

D·2·1


TURBINE
STEAM →
Boiler
CONDENSER
CONDENSATE
←
RETURN
HEAT
COOLING

SLIDE #1

water is boiled and the steam generated is carried off to do some work. In order to make the transfer of heat more efficient we do not heat a large container of water but rather force the water to pass through hundreds of tubes which are all heated by the burning fuel oil.

Look at slide number two. In slide number two you will see an illustration of how hot gas heats a boiler tube wall. The heat is conducted through the tube wall and heats the water. The water circulates and carries off the heat, allowing cooler water to come into the tube where it in turn will be heated. Several things can occur to prevent this transfer of heat.

SEE PAGE 64A -- FOLLOWING

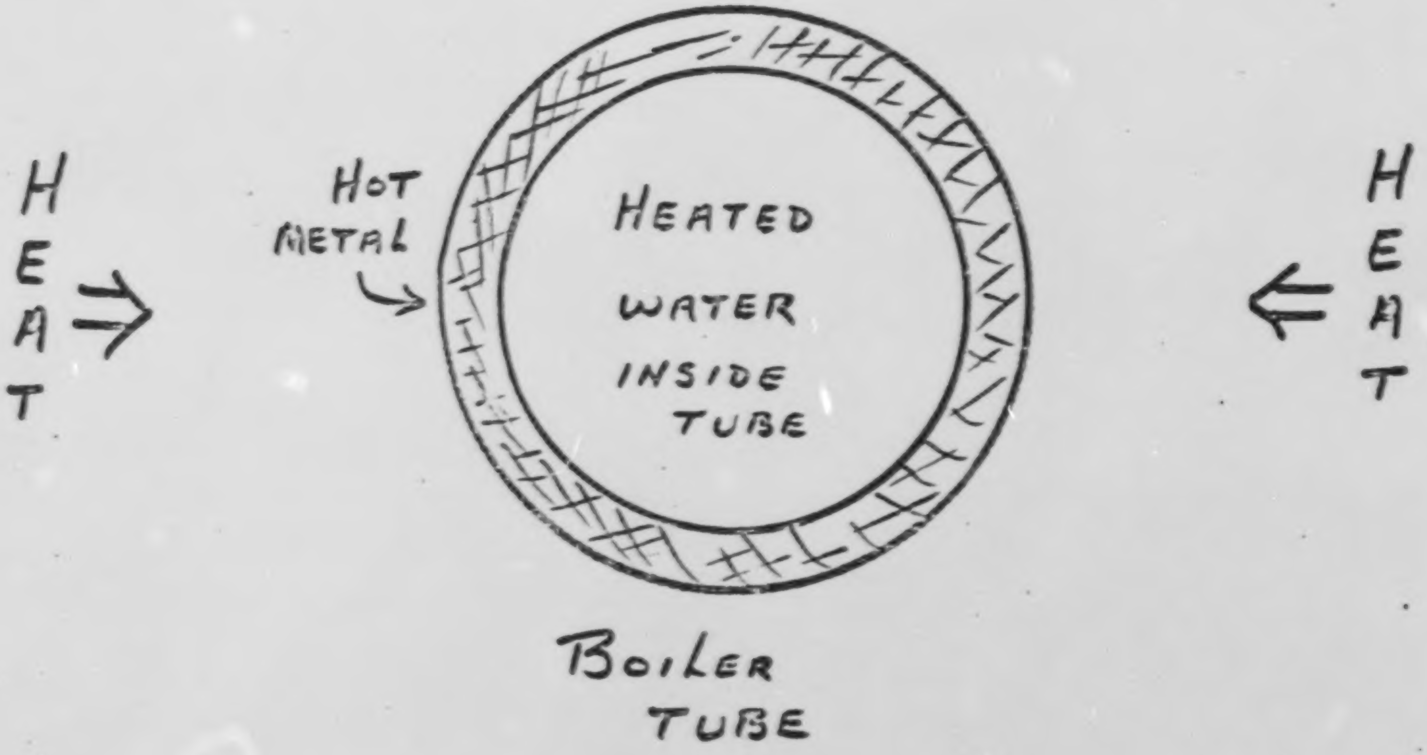
SLIDE #2

Look at slide number three. Improper control of the combustion process can cause a buildup of carbon products on the fire side of the tube wall. This coating will insulate the tube and prevent heat transfer. On the water side of the tube a layer of scale can build up which will also slow down the heat transfer. This scale is formed by the mineral salts

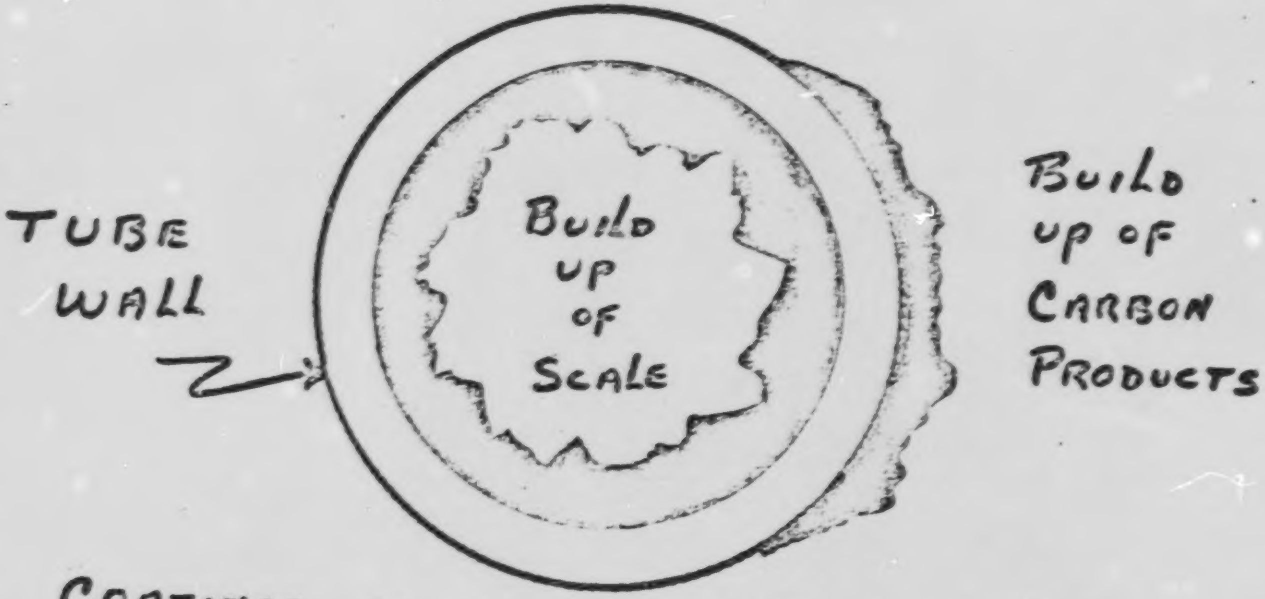
SEE PAGE 64B -- FOLLOWING

SLIDE #3

SLIDE #2


HEAT
HOT METAL
HEATED WATER INSIDE TUBE
HEAT
BOILER TUBE

SLIDE #3


TUBE WALL
Build up of Scale
Build up of Carbon Products

COATINGS ON FIRESIDE AND WATERSIDE PREVENT HEAT TRANSFER TO THE BOILER WATER in water precipitating out and adhering to the tube wall. These salts constitute the "hardness" of the water.

Advance your carrousel to slide number four, The heat transfer can also be affected by a physical or chemical weakening of the tube wall structure. This weakening of the tube wall is called corrosion and leads to holes, leaks, and even bursting tubes. In Unit C-4 (Corrosion) we will examine corrosion more fully.

SEE PAGE 65A -- FOLLOWING

SLIDE #4

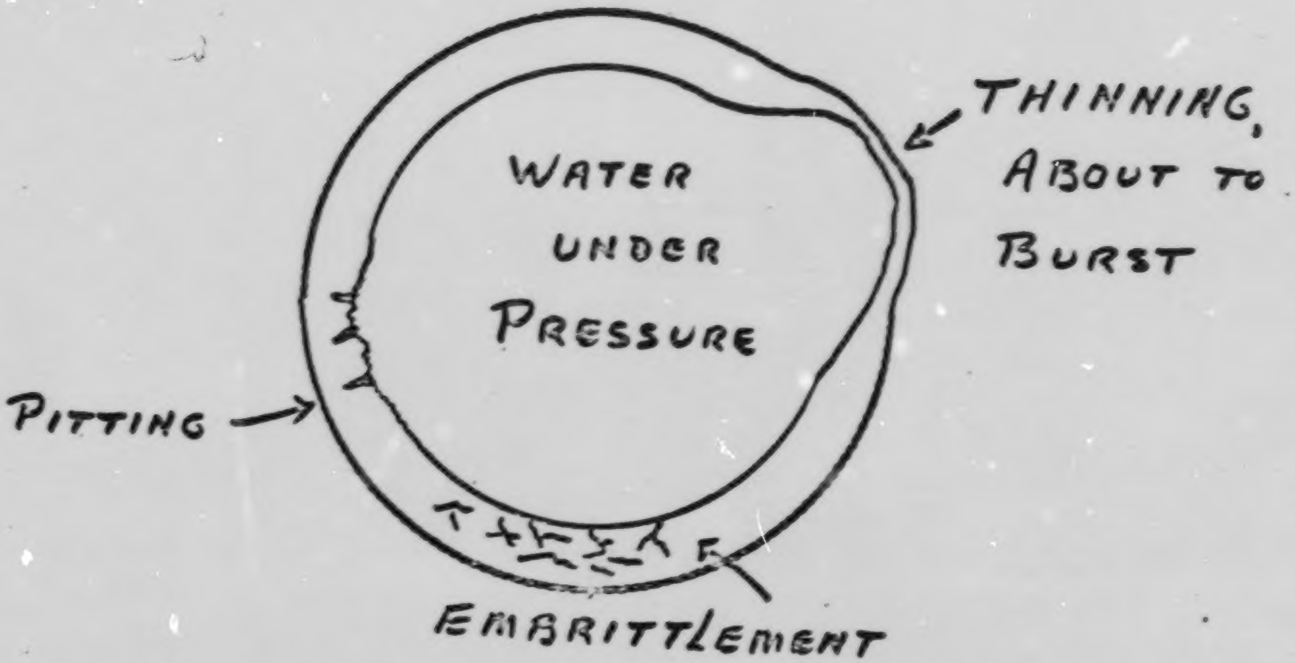
Now I would like you to go to the bench where the sample boiler water tubes are on display. Examine the different ones and note the effects of scale formation and corrosion. Please do not pick at the scale for this will ruin the sample.

Advance your carrousel to slide number five. There are several reasons why scale forms. Some materials become less soluble as the temperature of the solvent rises and therefore begin to precipitate out. Also, as the water leaves the boiler in the form of steam, the materials

1. Some materials become LESS soluble as the temperature rises.
2. As the water turns to steam it leaves the impurities behind As their concentration increases they begin to precipitate out.

SLIDE #5

SLIDE #4


WATER UNDER PRESSURE
THINNING, ABOUT TO BURST
PITTING
EMBRITTLEMENT

CORROSION: A STRUCTURAL WEAKENING DUE TO PHYSICAL OR CHEMICAL CAUSES dissolved in it are left behind. As their concentrations increase they begin to precipitate out.

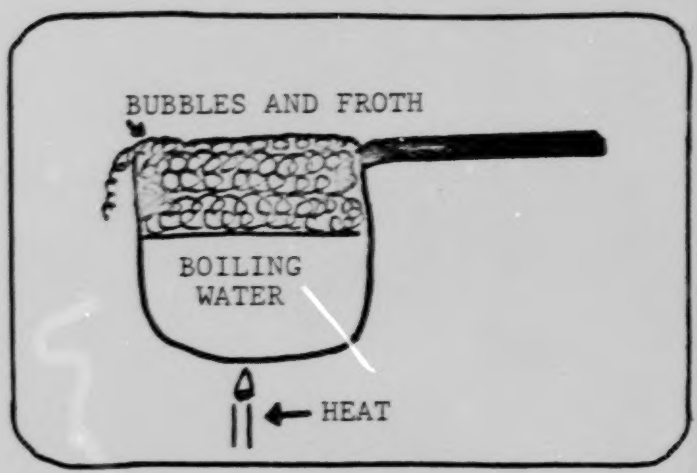
Look at slide number six. There are several steps we can take to prevent scale formation. First, we can remove the scale forming materials from the water before we use it. This is done in the evaporator where we distill the sea water and use the distilled water for our makeup feed water. Theoretically, only the water vapor should go from one stage of the evaporator to another, but sometimes molecules of the impurities are carried over. Sometimes, especially as the concentration of the impurities increases, a foaming, bubbling layer, such as occurs on a pot of spaghetti, forms and some of the bubble films carry over and contaminate the distilled water condensate.

SCALE PREVENTION

1. Remove scale forming materials from the water before using it.
2. Add chemicals to form NON-ADHERING precipitates called SLUDGE.

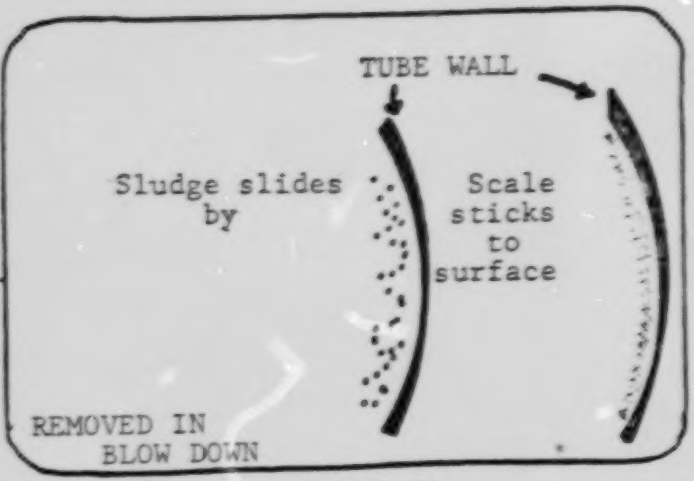
SLIDE #6

Look at slide number seven. We prevent carryover and foaming by adding chemicals to the sea water in the evaporators. We can prevent the impurities in the makeup feed water from precipitating out and forming



SLIDE #7

scale by making them precipitate out in a form which will not adhere to the tube walls but remains suspended as a non-adhering sludge.



SLIDE #8

Advance your carrousel to slide number eight. The chemical added to force this reaction is a type of phosphate. When the boiler water is tested it is checked for hardness. Since the chloride ion (Cl) is the easiest to measure, the chlorinity of the water is measured and this tells us the amount of salts in the water. We also measure the amount of phosphate present to see if there is enough to do the job, but not so much as to cause other problems.

CORROSION: A structural weakening of a metal due to either physical or chemical causes.

SLIDE #9

Look at slide number nine. Corrosion is the process of wearing away or weakening a metallic structure by physical or chemical means. The corrosion due to chemical causes can be retarded if not prevented by chemical additives.

ENEMY OF METAL:

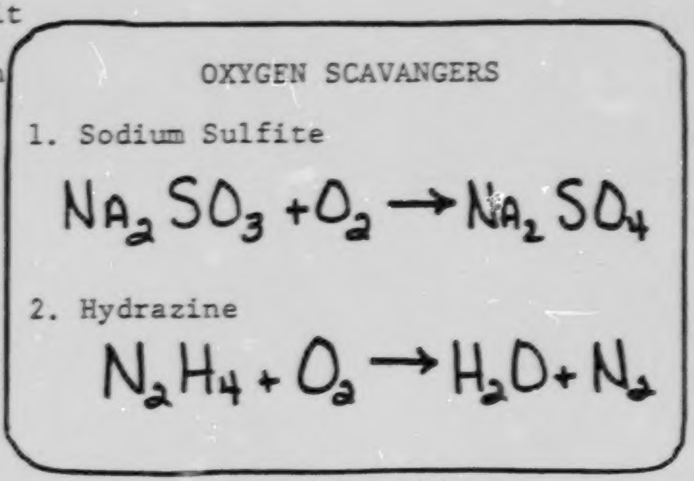
1. Acid solution
2. Presence of oxygen

SLIDE #10

Now advance your carrousel to slide number ten. We have already seen that acids react with metals. In order to prevent this reaction from taking place in the boiler, chemicals are added to make the water "basic" or "alkaline", rather than "acidic". One chemical which is used is caustic soda or sodium hydroxide (NaOH). The sodium hydroxide is a strong base and should not be allowed to come in contact with your skin. Several alkalinity tests are used to determine the acidity or alkalinity (How basic) of boiler water.

Oxygen reacts with metals to form oxides which can weaken the structure of the metal. We can remove the dissolved oxygen from water by heating it. This is done in the deaerating heater. The small amount of dissolved oxygen which remains is removed by adding a chemical which reacts with it to form harmless compounds. Two such chemicals, called oxygen scavangers, are shown in slide number eleven.

Advance your carrousel to slide number eleven. The two oxygen scavangers commonly used are sodium sulfite (Na_2SO_3), which reacts with the dissolved oxygen to form sodium



OXYGEN SCAVANGERS

1. Sodium Sulfite

$$Na_2SO_3 + O_2 \rightarrow Na_2SO_4$$

2. Hydrazine

$$N_2H_4 + O_2 \rightarrow H_2O + N_2$$

SLIDE #11

sulfate, and hydrazine (NH_2NH_2).

The hydrogen reacts with any dissolved oxygen to form nitrogen gas (Na) and water (H_2O). In any case, in the testing of boiler water we measure the amount of the oxygen scavanger present in the water. The Bull and Roberts Company call their sulfite product Broxgon.

Look at slide number twelve. As the water leaves the boiler in the form of steam, some of it is lost in the cycle through steam leaks and so additional water must be added. Gradually the sludge deposits begin to get too plentiful causing secondary problems. The amount of dissolved solids can be measured with a meter called a TDS meter (Total Dissolved Solids). The use of the instrument in the conducting of these various tests will be explained shortly, but first, let's review some basic laboratory techniques and regulations.

SEE PAGE 69A -- FOLLOWING

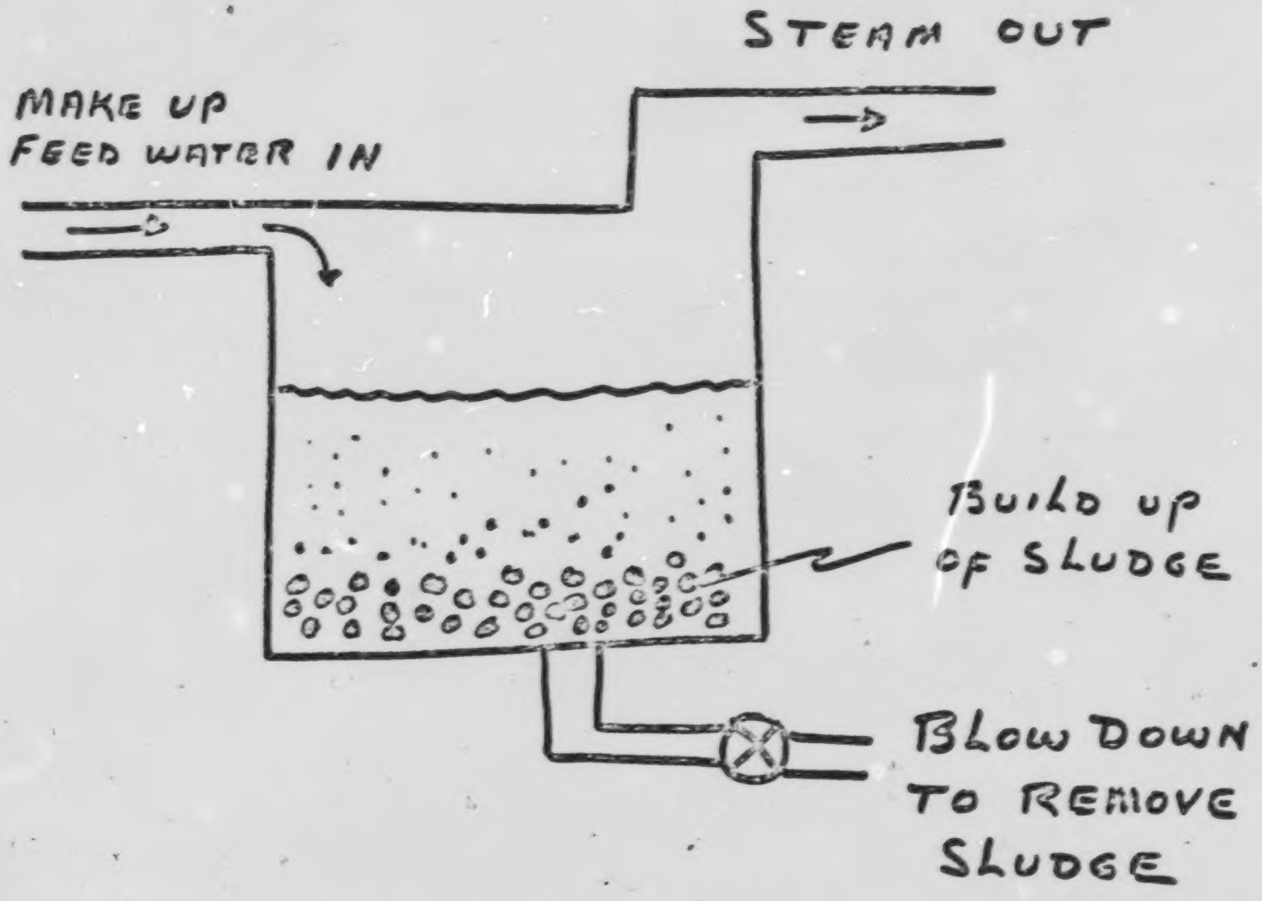
SLIDE #12

Advance your carrousel to slide thirteen. Always handle reagents so as to prevent splashing,

Handle reagents so as to prevent:

- splashing
- splattering
- spilling

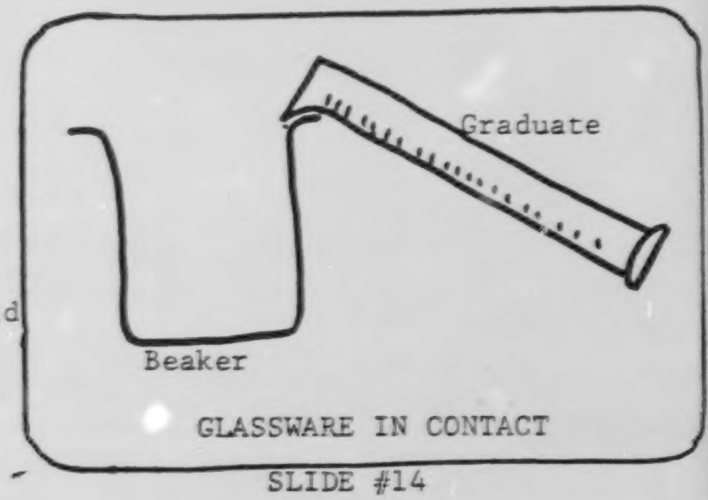
SLIDE #13


STEAM OUT
MAKE UP FEED WATER IN
BUILD UP OF SLUDGE
BLOW DOWN TO REMOVE SLUDGE

SLIDE #12

splattering, or spilling.

Look at slide number fourteen. Always keep glassware items in contact with one another when transferring the contents from one to another. In addition, always hold glassware securely or rest it on a bench.



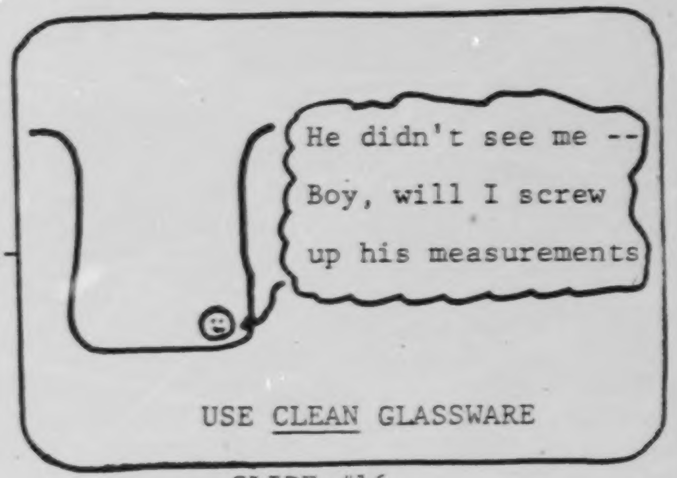
SLIDE #14

Look at slide number fifteen. Always double check labels to make sure you are using the correct reagent. Mixing together the incorrect reagents will often yield more than just the incorrect results.

ALAS!! POOR JAMES IS DEAD --
HE'LL MAKE THAT MISTAKE NO
MORE, FOR WHAT HE THOUGHT
WAS
H_2O
WAS
H_2SO_4

SLIDE #15

Look at slide number sixteen. We will be measuring very small amounts of substances present in a water sample. A dirty flask or beaker can cause you to get an incorrect result in a test. Dirt may also contribute more salt to the test results than the water that was being tested does. In order to avoid these problems always clean your glassware before and after it is used.


He didn't see me -- Boy, will I screw up his measurements
USE CLEAN GLASSWARE

SLIDE #16

Look at slide number seventeen. In slide number seventeen you will find some hints which help to prevent the contamination of reagents:

1. Keep containers closed.
2. Do not return excess reagents to the dispensing bottle.

Look at slide number eighteen. Here you will find come hints to help keep yourself and your clothes from being damaged by chemicals:

1. Rinse any areas of skin, clothes, or desk with water if chemicals spill on them.
2. Do not lay wet stirring rods down on the table. Dry them off or stand them in a beaker

Advance your carrousel to slide number nineteen. This slide illustrates how the automatic zeroing burettes are filled. Pump the bulb lightly. The liquid will be forced up the inner tube and will fill up the outer tube. When the liquid level has reached slightly above the zero mark stop pumping. The excess liquid will drain off back down the inner tube leaving the level at the zero mark. If you get too much liquid above the zero level it will come out the safety air hole at the top of the burette splattering the desk and probably you. If you pump too hard, the cork might be forced

SEE PAGE 71A -- FOLLOWING

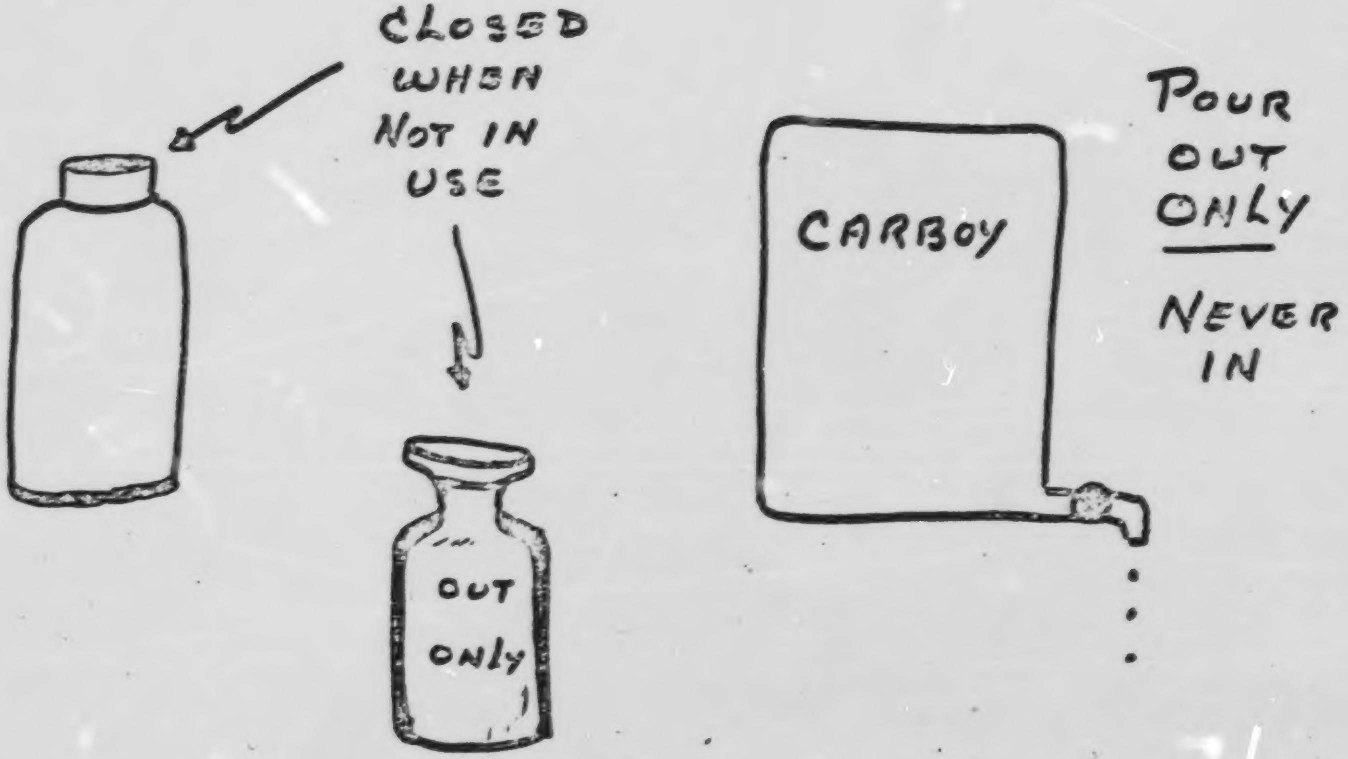
SLIDE #17

1. Rinse off any spilled chemicals.
2. Dry off wet stirring rods before laying them down.

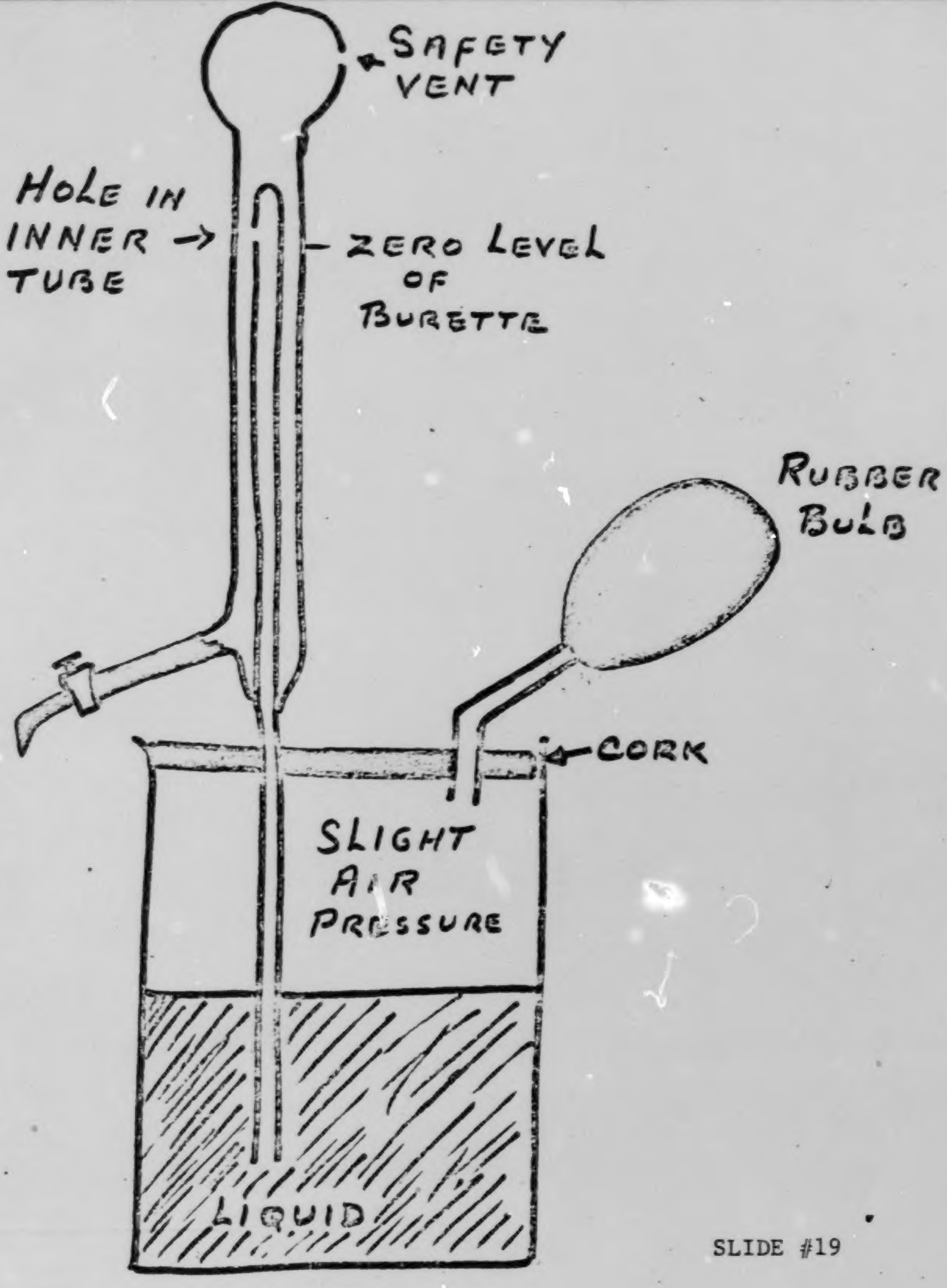
SLIDE #18

SEE PAGE 71B -- FOLLOWING

SLIDE #19


CLOSED WHEN NOT IN USE
OUT ONLY
CARBOY
POUR OUT ONLY
NEVER IN

SLIDE #17


SAFETY VENT
HOLE IN INNER TUBE
ZERO LEVEL OF BURETTE
RUBBER BULB
CORK
SLIGHT AIR PRESSURE
LIQUID

SLIDE #19

out of the bottle by the excess pressure. If you have trouble working the burettes ask the instructor for help.

Look at slide number twenty. This slide states a laboratory rule whose foundation is based upon laboratory safety considerations.

HORSEPLAY IN THE LAB
RESULTS
IN
SUSPENSION FROM COURSE

SLIDE #20

Look at slide number twenty-one. The first test to be done is one which, while not used much any more except aboard some Navy ships, is a standard test you should have seen at least once in your training. Slide number twenty-one shows the materials to be used in the conduct of this test. Open the booklet Chemical Analysis of Water by Drew Chemical Corporation to page number seven and read the instructions for Soap Hardness Test Number 1.

This slide shows a graduated cylinder marked at 58.3 ml; a 250 ml bottle with stopper; and a one liter bottle of soap solution with a 10 ml titrating burette inserted in the top.

SLIDE #21

Step number eight refers to a conversion table. This table is not in your manual. The lather factor of four tenths of a milliliter referred to is the amount of the standard soap solution required to maintain a five minute lather on a sample of water with zero hardness. As the hardness increases, so does the amount of soap solution required, one milliliter of solution for each increase of one grain per gallon of hardness.

When you do this test, omit step number nine.

Draw a water sample from the carboy labeled Boiler A and conduct this test. The value you should obtain for your result is posted on the carboy. If yourresult differs greatly from that which is posted, rerun the test.

Advance your slide carrousel to slide number twenty-two. The next several tests measure the alkalinity of the boiler water. In a later unit the alkalinity of solutions will be explained in detail. Now it is sufficient to say that there are several types of alkalinity measurements. These are illustrated on slide number twenty-two. Some confusion in terminology comes from the different names given to the same measurement by different companies.

ALKALINITY TESTS

Bull & Roberts	Drew Chemical Co.
Total "A"	Phenolphthalein
"M"	Total Alkalinity
Caustic "B"	Hydroxide Alkalinity

SLIDE #22

Slide number twenty-two shows the test names given by two companies. On any given ship you will be working with the chemical test set of only one company. Here in the lab we want you to gain experience doing the test according to the instructions of various companies so when you do encounter the different systems you will be at ease running the tests. We will run the tests first from the Drew Chemical Company Manual (which you just used for the soap test) and then we will run the tests from the Bull and Roberts Manual.

Look at slide number twenty-three. This slide shows the equipment used for the alkalinity tests. Read the instructions in the Drew Manual for test number three and number four, phenolphthalein alkalinity and total alkalinity. When you have finished reading the directions, bring the equipment to your bench and run the test. In the conduct of these tests, use water drawn from the carboy labeled "Boiler A". The results you should obtain are posted on the carboy. If

This slide shows the following equipment:

- one 100 ml beaker;
- a small bottle of Drew total alkalinity reagent;
- a small bottle of phenophthalein;
- a one liter bottle of .1N H_2SO_4 with a titrating burette inserted in the top; and
- an evaporating dish.

SLIDE #23

your results are far off, run the tests again. When you have finished the tests save the water sample but replace the other equipment and clean up your working area.

Advance your carrousel to slide number twenty-four. There are many ions formed when the various salts dissolve in water. One of the most common of these ions is the chloride ion (Cl^-). A good idea of the total quantity of salts in water may be obtained by measuring the chloride ion (Cl^-) content of the water. Slide number twenty-four shows the equipment needed to run the Drew chloride test (test number six). Use the water sample which was left over from the alkalinity tests you just did. Now, read the instructions and run the test. The results you should get are posted on the carboy from which you drew your sample. When you have finished clean up your equipment and replace the reagents.

This slide shows the following equipment:

a stirring rod

an evaporating dish

a small bottle of potassium chromate

a liter bottle of $AgNO_3$ with a titrating burette in its top

SLIDE #24

Look at slide number twenty-five. The previous tests were for boiler water conditions. At times, however,

CHLORIDE TEST -- ALTERNATE

TEST FOR SALT CONTENT IN FEED WATER, POTABLE WATER, CONDENSATE

READ DREW TEST #7

SLIDE #25

it will be necessary to test for chlorides (Cl) in the makeup feed water before it ever gets to the boiler. A test to accomplish this task is included in the Drew manual as test number seven. You may run this test if you wish. If you do run the test, take your sample from the carboy marked, "make-up feed water and potable water".

Look at slide number twenty-six. Bull and Roberts Company also has a test for chlorides (Cl) in make-up feed water. The test is described in the Bull and Roberts Marine Instruction Manual on page A-10. You should read these instructions most carefully. There are several differences between this test and the Drew test. In the Bull and Roberts test a larger volume of sample is used. Use of the larger volume allows more accurate results. Also, it is presumed that the water has the necessary alkalinity so the addition of the phenolphthalein and sulphuric acid is omitted. The counting of drops instead of reading burette levels is also a variation,

BULL & ROBERTS

ALTERNATE CHLORIDE TEST

PG A - 10

MAKE UP FEED AND POTABLE WATER

SLIDE #26

but just as accurate since all the drops should be nearly the same size. If you wish, you may run this test now.

When you are tested on this unit you will be given a sample of water to test, and be told what to test for and which manual to use. You may be asked for any of the tests in this unit. So, even though you feel that there is nothing new in the test procedure, a little extra practice may be of great benefit to you. If you plan to run the Bull and Roberts Condensate Salinity test, use the water from the carboy marked "make-up-feed water and potable water".

Advance your slide carrousel to slide number twenty-seven. You have run the alkalinity tests and the chloride tests from the Drew Chemical Company booklet, Chemical Analysis of Water, and now you will do the tests as described in the Bull and Roberts manual starting on page A-5. Read the instructions and perform the tests described as Total Alkalinity "A" reading, Chloride Test

BULL & ROBERTS PG A - 5

ALKALINITY

CHLORIDE

BOILER "A"

SLIDE #27

(Salinity), and Caustic Alkalinity "B" reading. When you run the tests be sure to use the correct reagents since even though the bottles have the same names, the companies sometimes differ in the concentrations of the chemicals they use in their test cabinets. Use the water from the carboy marked "Boiler A" in the conduct of these tests. When you have finished conducting these tests, clean your glassware and working area.

Look at slide number twenty-eight. Open the instruction manual by Maritec Corporation titled, Practical Water Treatment for Marine Boilers, 800 to 1,500 PSIG, and turn to pages 7, 8 and 9.. Read the instructions for the soap hardness, alkalinity, and chloride tests. Compare them with tests you have already done. Are they the same, or do they differ in any way?

This slide shows a book titled, PRACTICAL WATER TREATMENT FOR MARINE BOILERS 800 PSIG to 1500 PSIG, by Magnus Maritec.

SLIDE #28

Look at slide number twenty-nine. You probably recognized the tests. All of these tests are described in the manual Standard Methods for the Examination of Water and Wastewater,

This slide shows a text titled, STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER.

SLIDE #29

which is shown on slide number twenty-nine. The library has a copy of this manual at the instructor's desk. Look at the description of the chloride test on page 96. Is it familiar?

Advance your carrousel to slide number thirty. In order to prevent scale formation the marine engineer adds some phosphates to the boiler water. The exact amount required has been worked out by a chemical engineer. A chart showing how much phosphate should be added based upon the marine engineer's phosphate measurements has been derived from the chemical engineer's work. The test is the same for both the Drew and the Bull and Roberts manuals, but the equipment used is different and again, the concentration of reagents is different. Read page 16, test 8, of the Drew manual carefully. Then read the Bull and Roberts manual page A-7 and run the test for phosphate using each method. Remember to use the reagents and equipment which go together. Also, keep them together when you replace them. The

DREW MANUAL

PAGE 16 TEST 8

BULL & ROBERTS MANUAL

PAGE A - 7

USE BOILER "B"
PHOSPHATE TEST

SLIDE #30

small glass tubes are expensive! Please handle them with care. Use the water from the carboy marked "Boiler B". The correct valve of the phosphate is marked on the carboy.

Look at slide number thirty-one. Slide number thirty-one shows you how to fold the filter paper.

Now advance your carrousel to slide number thirty-two. It shows the equipment required to run the Bull and Roberts test for the sulfite oxygen scavanger which they call Broxgon (Bull and Roberts Oxygen gone). Read the instructions on page B-3 of the Bull and Roberts manual and then run the test. In the conduct of the test use the water from the carboy marked "Boiler B". The correct valves for the test results are posted on the carboy.

Look at slide number thirty-three. This slide shows the equipment required to run the sulfite test described in the Drew manual on page 19 (test #13). Use the water from the carboy marked "Boiler B" for the test.

SEE PAGE 80A -- FOLLOWING

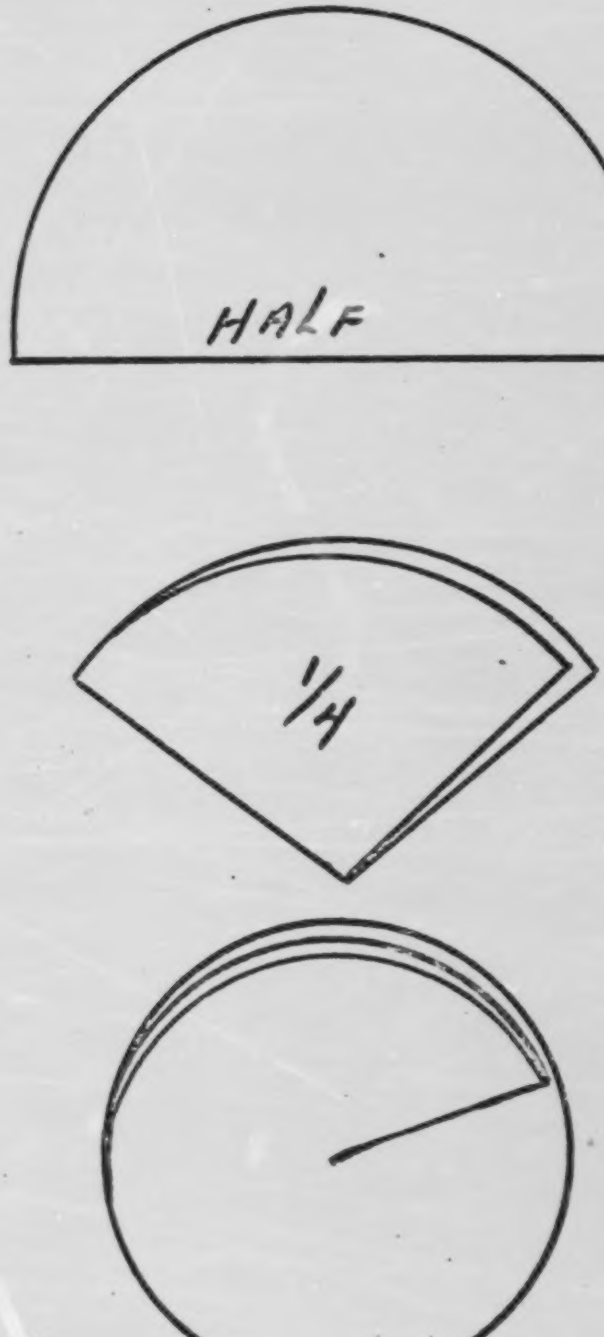
SLIDE #31

This slide shows filter paper; a brass measuring spoon; a glass funnel; a 100 ml graduated cylinder; a liter bottle of Bull and Roberts colorimetric phosphate; two square test tubes graduated to 10 ml; a Bull and Roberts color disc holder; a Drew phosphate comparator graduated in ppm PO_4; a small container of stannous chloride; and a ½ liter bottle of Drew Molybdate reagent.

SLIDE #32

This slide shows a 100 ml graduated cylinder; an evaporating dish; a stirring rod; a brass measuring spoon; a small bottle of acid starch indicator; and a bottle of potassium iodide iodate with a titrating burette inserted in it.

SLIDE #33



Do Not
Fill
Funnel
More
Than
2/3
Full

Advance to slide number thirty-four. The second type of oxygen scavanger is hydrazine (NH_2NH_2). Bull and Roberts call their compound Bramine. Read the bramine control test instructions in the Bull and Roberts manual on page D-3 and run the test. Use a water sample from the carboy marked "Boiler C" in the conduct of this test.

BULL & ROBERTS BRAMINE TEST

PAGE D-3

BOILER "C"

SLIDE #34

Advance your slide carrousel to slide number thirty-five. This slide shows the reagents and equipment necessary to run the Drew Hydrazine test as described on page 16 of the Drew Manual. Use a sample of water from the carboy marked "Boiler C" in the conduct of this test.

This slide shows a Drew hydrazine comparator graduated in ppm; a small test tube graduated to 10 ml; and a bottle of Amerzine reagent.

SLIDE #35

Look at slide number thirty-six. This slide shows the Bull and Roberts TDS meter. Open the Bull and Roberts manual to page A-21 and read the instructions for testing Boiler water samples. It gives eight steps. You do not have to do the feedwater or other tests. Use a sample from the carboy marked "Boiler B" to make your

This slide shows a Bull and Roberts Dissolved Solids Meter; a 100 ml graduated cylinder; a bottle of Total Dissolved Solids reagent solution; a thermometer; and a small bottle of phenolphthalein.

SLIDE #36

measurements.

Advance your carrousel to slide number thirty-seven. This shows the equipment needed to run the TDS measurement using the Drew TDS meter. Open the Drew manual to page 26 and read the instructions for test number 15. Use a sample of water from the carboy marked "Boiler B" for making the measurements.

This slide shows a Solu Bridge and associated probe, and a graduated cylinder.

SLIDE #37

Advance your carrousel to slide number thirty-eight. The tests you have completed in this unit are listed on slide number thirty-eight. In order to receive a passing grade for this unit you will have to take a sample of water and run a set of tests on it, using your manuals, but working alone. Your results will be turned in to the instructor for evaluation. If you should fail to obtain the proper results, you will be requested to run another set of tests.

alkalinity
hardness (soap)
chloride
sulfite
hydrazine
phosphate
TDS

SLIDE #38

There is an optional module which you can elect to meet your "B" level or "A" level requirements called Advanced Boiler Water Testing. This module will take you through the tests for high pressure boilers and the measuring for trace elements like silica, copper and iron. If you found this module interesting you will enjoy that one also.

MODULE D-2 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G. H., and Augustine, F. B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the Module D-2 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to Module D-2 as well as to the completion of the problem set. Those pages are 65, 79, 84-91, 100, 114-116, 200, 203-206, 216, 222-230, 276-278.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown. (Read across)

Page	Problems
101	1, 4, 5, 6, 7
117	7, 8
218	1
241	8, 9
280	11, 12

MODULE D-2 PROBLEM SET SOLUTIONS

Page Problem

101 (1) Given $\begin{cases} V = 12.7 \text{ l at } 655 \text{ Torr} \\ \text{Temp}_1 = \text{Temp}_2 \end{cases}$

Pressure at V = 20.0 l = ?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$P_1V_1 = P_2V_2$$

$$655 \text{ Torr} \times 12.7 \text{ l} = P_2 \times 20.0 \text{ l}$$

$$P_2 = \frac{655 \text{ Torr} \times 12.7 \text{ l}}{20.0 \text{ l}}$$

$$= \frac{8318.5 \text{ Torr}}{20.0 \text{ l}}$$

$$= 415.9 \text{ Torr}$$

101 (4) Given $\begin{cases} 120 \text{ Atmospheres at } 25^\circ \text{ C} \\ 50 \text{ Atmosphere Safety Factor} \\ \text{Assume } V_1 = V_2 = 1 \text{ l} \\ 170 \text{ Atmospheres at } ?^\circ \text{ K} \end{cases}$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$T_2 = \frac{P_2T_1}{P_1} \qquad T_1 = 25^\circ\text{C} + 273 = 308^\circ\text{K}$$

$$= \frac{170 \text{ ATM} \times 308^\circ\text{K}}{120 \text{ ATM}}$$

$$= \frac{5236^\circ\text{K}}{12}$$

$$= 422^\circ\text{K vice } 436.3^\circ\text{K}$$

Page Problem

101 (5) a. $0^\circ C + 273 = 273^\circ K$

b. $25^\circ C + 273 = 298^\circ K$ vice $308^\circ K$

c. $100^\circ C + 273 = 373^\circ K$

101 (6) Given $\begin{cases} 15.0 \text{ l at } 25^\circ C \\ P^1 = P^2 \\ T^1 \text{ at } 8.5 \text{ l} = ? \end{cases}$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad T_2 = \frac{V_2 T_1}{V_1} \qquad T_1 = 25^\circ C + 273 = 308^\circ K$$

$$= \frac{8.5 \text{ l} \times 308^\circ K}{15.0 \text{ l}}$$

$$= \frac{2618^\circ K}{15}$$

$$= 169^\circ K \text{ or } -104^\circ C$$

101 (7) Given $\begin{cases} 3.60 \text{ l at } 20^\circ C \text{ \& } 720 \text{ Torr} \\ \text{at STP, } V = ? \end{cases}$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T2} \qquad \begin{aligned} T_1 &= 20^\circ C + 273 = 293K \\ T_2 &= 273K \\ P_2 &= 760 \text{ Torr} \end{aligned}$$

$$\frac{P_1 V_1 T_2}{T_1 P_2} = V_2$$

$$V_2 = \frac{720 \text{ Torr} \times 3.60 \text{ l} \times 273^\circ K}{293^\circ K \times 760 \text{ Torr}}$$

$$= \frac{72201.6 \text{ l}}{22268}$$

$$= 3.18 \text{ l}$$

117 (7) Temperature drop = $75^\circ C$
1 Mole $H_2O = (2 \times 1.007)g + 15.999g$
$= 18.013g$

1 calorie removed per gram H_2O per degree drop

75 calories removed per gram H_2O

18.013 H_2O x 75 calories = 1350.9 cal

Page	Problem	
117	(8)	540 Cal + 100 Cal + 80 Cal = 720 Cal to change 1g H_2O from steam to ice $18.013\text{g} \times \frac{720\text{ Cal}}{1\text{g}} = 12969.36\text{ Cal}$
218	(1)	At 20°C, 57g/100g H_2O At 80°C, 100g/100g H_2O Approximately 50% precipitates
241	(8)	H^+ ion concentration = 10^{-6} Therefore pH = 6
241	(9)	OH^- ion concentration = 10^{-6} pOH = 6 pH = 14 - pOH = 14 - 6 = 8
280	(11)	$$\left.\begin{array}{ll}\text{Silver Chloride} & 1.7 \times 10^{-10} \\ \text{Silver Bromide} & 3.3 \times 10^{-13} \\ \text{Silver Iodide} & 8.5 \times 10^{-7}\end{array}\right\}\ \text{Solubility product constant}$$ They follow a predictable periodic relationship
280	(12)	a. $K_{sp} = 1.3 \times 10^{-51}$, $[Ag]^2[S]$ b. $K_{sp} = 3.5 \times 10^{-9}$, $[Ca][CO_3]$ c. $K_{sp} = 8 \times 10^{-15}$, $[Ca][F]^2$

MODULE D2 - 1 EXAMINATION

Name ____________________ Date ____________________

Time Started ______________ Time Finished ______________

Instructor ______________ TIME LIMIT: ONE HOUR

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Bull and Roberts

Total Alkalinity - "A" Reading ______________

Caustic Alkalinity - "B" Reading ______________

Broxgon

Drew

Alternate Chloride Test ______________

Hydrazine ______________

Phosphate (Excess) ______________

Any TDS (Total Dissolved Solids) ______________

Sample Used ____________________

MODULE D2 - 2 EXAMINATION

Name ______________________________ Date ____________________

Time Started ______________________ Time Finished ___________

Instructor _________________________ TIME LIMIT: ONE HOUR

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Run an alternate chloride test (Drew) on the tap water Potable Water Cl. ________________ppm

Drew

"P" Alkalinity ________________ppm

"T" Alkalinity ________________ppm

Hydrazine ________________ppm

Bull and Roberts

Phosphate ________________ppm

Broxgon ________________ppm

Any TDS (Total Dissolved Solids) ________________ppm

Sample Used _________________________

MODULE D2 - 3 EXAMINATION

Name ______________________________ Date __________________________

Time Started ____________________ Time Finished _______________

Instructor ______________________ TIME LIMIT: ONE HOUR

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Drew

"P" Alkalinity _________________ppm

"T" Alkalinity _________________ppm

Chloride _________________ppm

Bull and Roberts

Phosphate _________________ppm

Bramine _________________pH

Broxgon _________________ppm

Any TDS (Total Dissolved Solids)_________________ppm

Sample Used ________________________________

MODULE D2 - 4 EXAMINATION

Name ____________________ Date ____________________

Time Started ____________________ Time Finished ____________

Instructor ____________________ TIME LIMIT: ONE HOUR

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Bull and Roberts

"A" Reading - Alkalinity ____________ ml

Chloride ____________ gpg

"B" Reading ____________ ml

Drew

Phosphate ____________ ppm

Sulfite ____________ ppm

Hydrazine ____________ ppm

Any TDS (Total Dissolved Solids) ____________ ppm

Sample Used ______________________

MODULE D2 - 5 EXAMINATION

Name ____________________ Date ________________

Time Started ______________ Time Finished ________

Instructor ______________ **TIME LIMIT: ONE HOUR**

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Bull and Roberts

Total Alkalinity - "A" Reading ________________

Caustic Alkalinity - "B" Reading ________________

Broxgon ________________

Drew

Phosphate ________________

Sulfite ________________

Hydrazine ________________

Any TDS (Total Dissolved Solids) ________________

Sample Used ______________________

MODULE D2 - 6 EXAMINATION

Name ______________________ Date ______________________

Time Started ______________ Time Finished ______________

Instructor ________________ TIME LIMIT; ONE HOUR

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Drew

Alternate Chloride Test ______________________

Hydrazine ______________________

Any TDS (Total Dissolved Solids) ______________________

Bull and Roberts

Phosphate ______________________

Bramine ______________________

Broxgon ______________________

Sample Used ______________________

MODULE D2 - 7 EXAMINATION

Name ______________________________ Date ______________________

Time Started _____________________ Time Finished ____________

Instructor _______________________ TIME LIMIT: ONE HOUR

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Bull and Roberts

Chloride ____________________

"A" Reading (Alkalinity) ____________________

Caustic Alkalinity - "B" Reading ____________________

Drew

Hydrazine ____________________

"T" Alkalinity ____________________

Sulfite ____________________

Phosphate (Excess) ____________________

Sample Used _________________________________

MODULE D2 - 8 EXAMINATION

Name ______________________ Date ______________________

Time Started ______________________ Time Finished ______________________

Instructor ______________________ **TIME LIMIT: ONE HOUR**

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Drew

Chloride ______________________

"P" Alkalinity ______________________

Phosphate ______________________

Bull and Roberts

Bramine ______________________

"B" Reading ______________________

Hydrazine ______________________

Any TDS (Total Dissolved Solids) ______________________

Sample Used ______________________

MODULE D2 - 9 EXAMINATION

Name ______________________ Date ______________________

Time Started ______________________ Time Finished ______________________

Instructor ______________________ **TIME LIMIT: ONE HOUR**

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Drew

Phosphate ______________________

Hydrazine ______________________

Sulfite ______________________

Bull and Roberts

Chloride ______________________

Broxgen ______________________

Caustic Alkalinity "B" Reading ______________________

Any TDS (Total Dissolved Solids) ______________________

Sample Used ______________________

MODULE D2 - 10 EXAMINATION

Name ______________________________ Date ________________________

Time Started ______________________ Time Finished _______________.

Instructor ________________________ **TIME LIMIT: ONE HOUR**

From the sample boiler water designated by the instructor, carry out the following tests and report your results below:

Bull and Roberts

Total Alkalinity - "A" Reading ________________________

Chloride ________________________

Phosphate ________________________

Drew

Hydrazine ________________________

Broxgon ________________________

Bramine ________________________

Any TDS (Total Dissolved Solids) ________________________

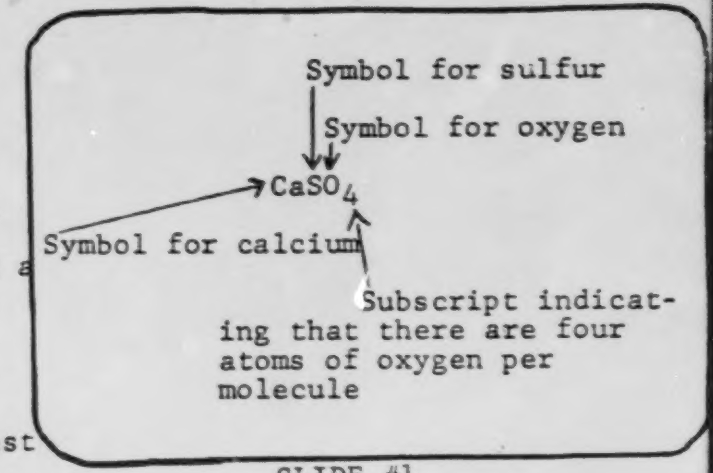
Sample Used ________________________________

MODULE C - 1 CHEMICAL REACTIONS

Chemical Reactions is the first of the modules with which you will work at the C level. As a result of C-1 module study you will be able to define, describe, illustrate, diagram and construct explanations for the following concepts: valence; Law of Conservation of Matter; chemical equations; oxidation-reduction reactions; cells; electrolysis; anion; cations; electrochemical corrosion; electronegativity; cathode protection; and heats of formation.

In this module, some of the various kinds of chemical reactions will be explored and we will try to develop some understanding of the reasons why chemical reactions occur. First, let us review symbols, formulas, and equations.

Advance your slide carrousel to slide number one. A chemical symbol represents one atom of an element in a formula. A formula represents one molecule of a substance, or in the case of ionic substances, the simplest


Symbol for sulfur
Symbol for oxygen
$CaSO_4$
Symbol for calcium
Subscript indicating that there are four atoms of oxygen per molecule

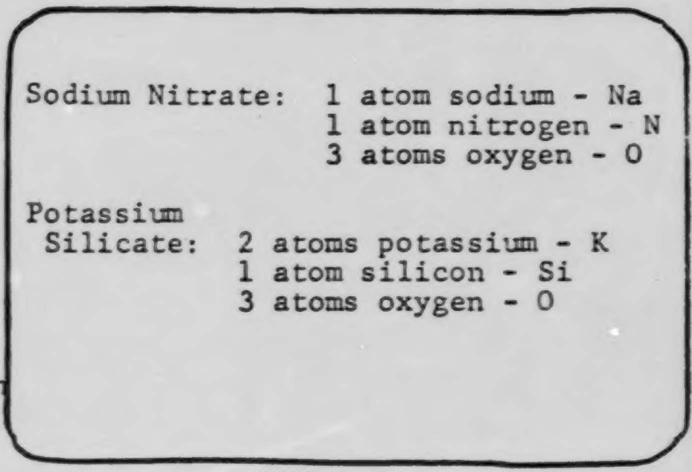
SLIDE #1

ratio of ions. Write the formula for a molecule of sodium nitrate. It contains 1 atom of sodium, 1 atom of nitrogen and 3 of oxygen.

Look at slide number two. Write the formula for potassium silicate which has the composition indicated on slide number two. When you have finished, look at slide number three and compare your answers with those found on slide number three.

Advance your carrousel to slide number four. Combining number, or valence, is the number of electrons an atom will gain, lose or share in forming a chemical bond. Hydrogen loses 1 electron and, therefore, has a combining number of +1. Oxygen readily gains 2 electrons and, therefore, has a combining number of -2.

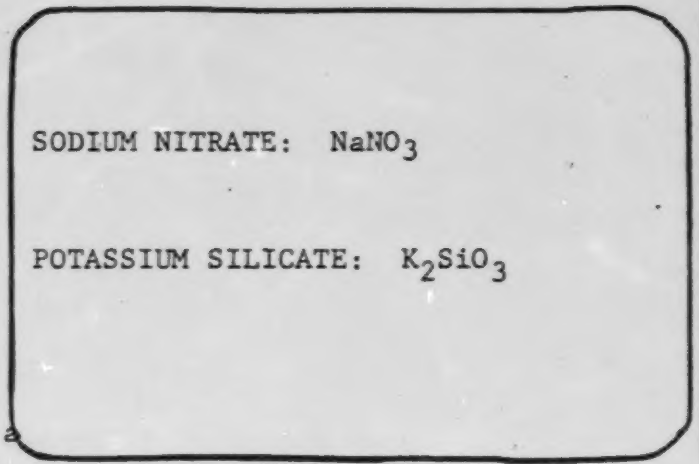
The combining numbers can be used to write formulas as indicated on slide number four. Write the combining number as a superscript after each symbol and put the atom with the positive combining number first. Then



Sodium Nitrate: 1 atom sodium - Na
1 atom nitrogen - N
3 atoms oxygen - O

Potassium Silicate: 2 atoms potassium - K
1 atom silicon - Si
3 atoms oxygen - O

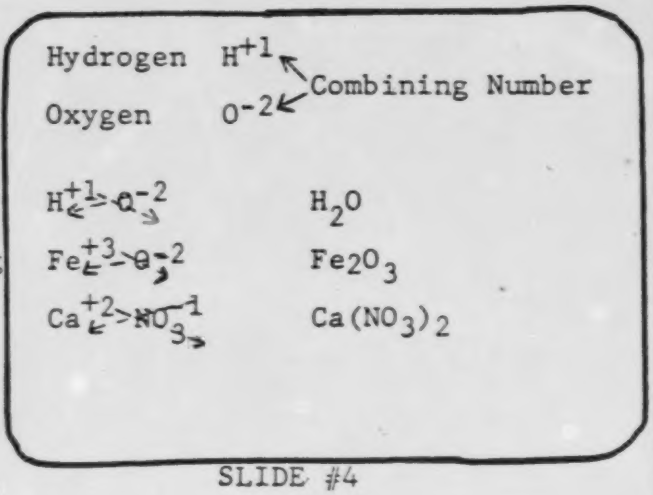
SLIDE #2



SODIUM NITRATE: $NaNO_3$

POTASSIUM SILICATE: K_2SiO_3

SLIDE #3



Hydrogen H^{+1}
Oxygen O^{-2}
Combining Number

$H^{+1}O^{-2}$ H_2O

$Fe^{+3}O^{-2}$ Fe_2O_3

$Ca^{+2}NO_3^{-1}$ $Ca(NO_3)_2$

SLIDE #4

cross as indicated. Study the iron oxide and calcium nitrate molecules. Note that when more than one radical is involved in a formula, brackets are used. The subscript outside the brackets indicates the number of radicals in the formula.

K^{+1} and SO_4^{-2}
Ca^{+2} and PO_4^{-3}
Al^{+3} and F^{-1}
Na^{+1} and SO_3^{-2}
Mg^{+2} and HCO_3^{-1}

SLIDE #5

Advance your carrousel to slide number five. Write the formulas for the combinations given on slide number five.

K_2SO_4	Potassium Sulfate
$Ca_3(PO_4)_2$	Calcium Phosphate
AlF_3	Aluminum Flouride
Na_2SO_3	Sodium Sulfite
$Mg(HCO_3)_2$	Magnesium Bicarbonate

SLIDE #6

Look at slide number six. If your answers are correct, go on. However, if they are not, you should return and try again. In addition, you should consult your text. You should be able to write chemical formulas if you are given the symbols and valences.

Look at slide number seven. An equation consists of a related group of formulas which represent a chemical reaction. The subgroup of formulas representing the materials which enter the reaction, that is, the reactants, are written on the left. The results, or products, are written on the right.

REACTANTS YIELD PRODUCTS

HYDROGEN GAS PLUS OXYGEN GAS
YIELD WATER

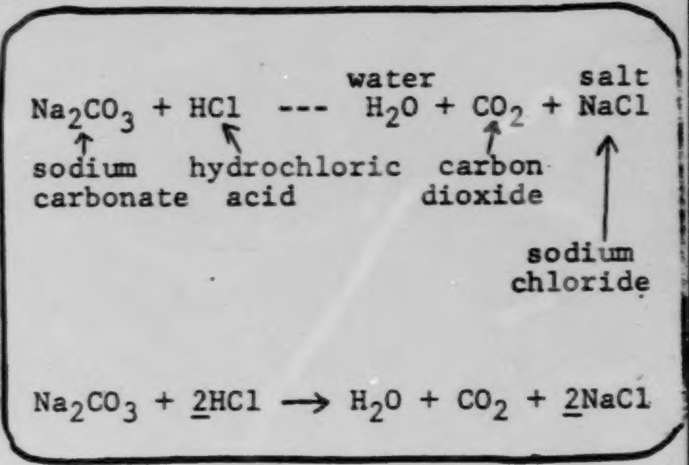
$$2H_2 + O_2 \longrightarrow 2H_2O$$

SLIDE #7

The arrow indicates that the reactants combine or interact to give the yield.

In a chemical reaction, matter is neither created or destroyed (this is called the Law of Conservation of Matter). Therefore, every atom entering the reaction must also come out of the reaction. All that the chemical reaction may do is change the arrangements of atoms.

Advance your slide carrousel to slide number eight. Notice that each molecule of sodium carbonate consists of two atoms of sodium. Notice that only one atom of sodium appears on the products side. Since sodiums cannot be destroyed and no other product contains sodium, there must be 2 molecules of sodium chloride. A coefficient of 2 is therefore placed before the sodium chloride (NaCl) in the lower balanced equation.



water salt

$Na_2CO_3 + HCl$ --- $H_2O + CO_2 + NaCl$

sodium carbonate hydrochloric acid carbon dioxide sodium chloride

$Na_2CO_3 + \underline{2}HCl \rightarrow H_2O + CO_2 + \underline{2}NaCl$

SLIDE #8

Note that the composition of formulas is not changed to balance the equation.

Two chlorines (Cl's) on the product side of the equation indicates that 2 chlorines (Cl's) must have entered the reaction. Chlorine enters the reaction only through the hydrochloric acid which contains one chlorine (Cl) per molecule. Therefore, two hydrochloric acid (HCl) molecules must have entered the reactions. In the balanced equation a 2 is put before the hydrochloric acid (HCl). The other atoms occur in equal numbers in both reactants and products side of the equation and so they are said to balance.

$\_H_2SO_4 + \_NaOH \longrightarrow \_Na_2SO_4 + \_H_2O$

$\_Fe + \_O_2 \longrightarrow \_Fe_2O_3$

$\_AgNO_3 + \_CaCl_2 \longrightarrow \_Ca(NO_3)_2 + \_AgCl$

SLIDE #9

Now look at slide number nine. Copy the equations onto a sheet of paper and balance them.

Look at slide number ten. Do your answers match those shown on slide ten? If they do not, restudy this section.

$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$

$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$

$2AgNO_3 + CaCl_2 \longrightarrow Ca(NO_3)_2 + 2AgCl$

NOTE: No coefficient before a formula means that the coefficient is 1.

SLIDE #10

As a result of studying this section, you should be able to balance the equations if you are given the formulas. You should also be able to recognize definitions of the terms which have been used in this section.

Advance your carrousel to slide number eleven. There are four basic types of reactions. Synthesis is simply a combination of elements or molecules. For example, the burning of hydrogen (H) produces water (H_2O); of coal, carbon dioxide (CO_2).

Synthesis: $A + B \rightarrow AB$
$H_2 + O_2 \rightarrow H_2O$

Decomposition: $AB \rightarrow A + B$
$H_2O \rightarrow H_2 + O_2$

Single Replacement: $A + BC \rightarrow AC + B$
$Zn + HCl \rightarrow ZnCl_2 + H_2$

Ion Exchange: $AB + CD \rightarrow AD + CB$
$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

SLIDE #11

Decomposition or analysis is the reverse of synthesis.

In single replacement reactions, one element in a compound is replaced by another. The action of acids on metals are classic single replacement reactions.

Ion exchange, or double replacement, amounts to a switching of the partners in a pair of molecules. These reactions often occur in solutions containing a number of salts. This type of reaction will go if water, gas or a precipitate are formed.

Advance your carrousel to slide number twelve. The double replacement reactions are not the reactions that take place in ion exchangers aboard ships. Those ion exchangers replace one kind of ion with another. Zeolite ion exchangers, for example, can remove

Sodium Zeolite + Calcium Ions → Sodium Ions + Calcium Zeolite

$Zeolite + Ca^{++} \rightarrow Na^{+} + CaZeolite$

SLIDE #12

calcium ions by replacing them with sodium. Hence, the term "exchange".

Look at slide number thirteen. Can you name the type of reaction for each example? Try it and then compare your answers with those given on slide number fourteen.

$C + O_2 \rightarrow CO_2$

$2HCl + Na_2SO_4 \rightarrow H_2SO_4 + 2NaCl$

$3H_2SO_4 + 2Fe \rightarrow Fe_2(SO_4)_3 + 3H_2$

$2HgO \rightarrow 2Hg + O_2$

$Cu + H_2S \rightarrow Cu_2S + H_2$

SLIDE #13

Look at slide number fourteen. If your answers do not match, see if you can determine why.

Synthesis - Combination:
$C + O_2 \rightarrow CO_2$

Ion Exchange - Double Replacement:
$2HCl + Na_2SO_4 \rightarrow H_2SO_4 + 2NaCl$

Single Replacement
$3H_2SO_4 + 2Fe \rightarrow Fe_2(SO_4)_3 + 3H_2$

Decomposition - Analysis
$2HgO \rightarrow 2Hg + O_2$

Single Replacement
$Cu + H_2S \rightarrow Cu_2S + H_2$

SLIDE #14

From this section, you should have learned the types of chemical reactions, and you should be able to identify and name them.

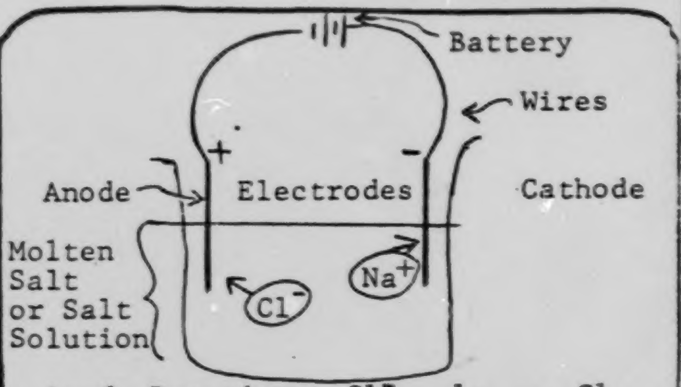
Advance your carrousel to slide number fifteen. Slide fifteen contains some oxidation-reduction reaction terms. Oxidation is defined as a loss of electrons; reduction as a gain. The cathode is the negative or electron rich pole of a cell. The anode is the positive, or electron attracting pole.

Ions attracted to the cathode are positive and are called cations. These are usually metallic. Anions are negative and are attracted to the anode. These are usually metallic or non-metallic radicals.

OXIDATION -- loss of electrons
REDUCTION -- gain of electrons
ANODE -- positively charged terminal of a cell or battery - electron poor
CATHODE -- negatively charged terminal of a cell or battery - electron rich
ANION -- negative ion in solution that is attracted to anode
CATION -- positive ion in solution that is attracted to cathode

SLIDE #15

Look at slide number sixteen. It shows a simplified diagram of the electrolysis of common table salt. The positive sodium ions are attracted to the cathode where they receive an electron each and become metallic sodium. At the anode the (negative) chloride anions lose electrons to form chlorine gas.



Anode Reaction:: Cl^- - le --- Cl
Cathode Reaction: Na^+ + le -- Na

SLIDE #16

Advance to slide number seventeen. Here is a list of cations and anions commonly associated with boiler water problems. You have analyzed for some of those ions in Module D-2 already.

CATIONS	ANIONS
Na^+	Cl^-
Mg^{++}	SO_4^{--}
Ca^{++}	HCO_3^-
K^+	Br^-
Sr^{++}	SiO_2

SLIDE #17

Electrochemical reactions probably have more application aboard ship than do electrolytic reactions. Electrochemical reactions cause most of the corrosion aboard ship; however, they can also be useful. Car batteries and flashlight batteries are common examples of electrochemical cells.

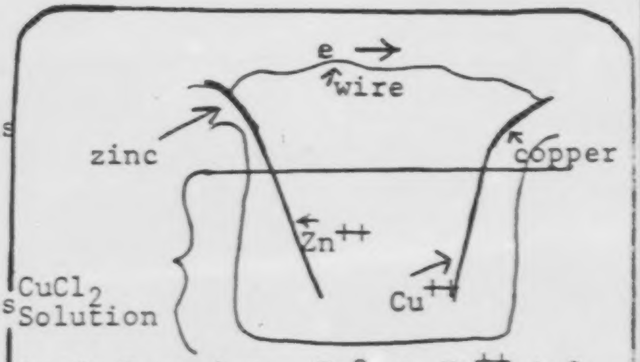
Look at slide number eighteen. Materials do not all have exactly the same tendency to gain or lose electrons. At the top of the column are materials which lose electrons easily, and at the

ELEMENT	POTENTIAL (VOLTS)
Na	+2.71
Mg	2.34
Zn	0.762
Fe	0.44
H	0.00
Cu	-0.345
Cl	-1.358
Mn	-1.52

SLIDE #18

bottom, materials which have a strong affinity for electrons.

The tendency to gain or lose electrons can be measured in volts by comparing each material to hydrogen in an electrochemical cell. That is how the emf series shown in slide number eighteen was determined.



Anode Reaction: $Zn^{o} \rightarrow Zn^{++} + 2e$

Cathode Reaction: $Cu^{++} + 2e \rightarrow Cu^{o}$

SLIDE #19

Look at slide number nineteen. If any two materials are put into contact with each other and are placed in a conducting solution, a reaction takes place. Zinc is more positive on the emf series. Therefore, it tends to lose electrons more easily than copper. Or conversely, copper has a greater affinity for electrons. Therefore, in the competition for electrons the zinc loses its electrons and goes into solution.

This slide shows a 400 ml beaker; a triple arm balance; a wire lead with alligator clips at both ends; two electrodes (pieces of metal), one zinc and the other copper; and a bottle of copper sulfate solution.

SLIDE #20

Advance your carrousel to slide number twenty and gather the materials shown there.

Look at slide number twenty-one. Here you see the materials shown in slide number twenty after they have been set up. Before putting the metal strips into the solution, clean them with

On this slide one sees a 400ml beaker containing a copper sulfate solution; two electrodes inserted into the solution (zinc and copper); and a wire lead connecting the two electrodes together.

SLIDE #21

steel wool and weigh them as accurately as possible, then connect them as shown. After about 15 minutes, remove the strips, note any changes, and re-weigh them.

Note that the zinc loses weight, therefore corrodes faster than the copper. What is happening is that the more active zinc, rather than the copper, corrodes. This principle is what keeps a galvanized plate from rusting until large portions of the zinc coat are gone. It is also the principle used in retarding the corrosion of a ship's hull.

Advance to slide number twenty-two. The STATE OF MAINE has zinc plates bolted to her hull to retard corrosion of the hull. The zinc plates eventually corrode and are replaced, but the hull does not corrode. We will do more with corrosion in a later module.

This slide shows a picture of zinc blocks bolted to the hull of a ship. The blocks are located close to the water line.

SLIDE #22

OXIDATION
REDUCTION
CATHODE
ANODE
CATION
ANION
ELECTROLYSIS

ELECTROMOTIVE SERIES

SLIDE #23

Look at slide number twenty-three. As a result of your study of this section you should be able to define the terms listed here. You should be able to make a labeled diagram of an electrolytic or electrochemical cell. In addition, given a pair of metals, you should be able to tell which one will corrode more rapidly if they are in contact, and finally, you should be able to explain why zinc plates are bolted to the hull of a steel ship.

Advance your carrousel to slide number twenty-four. In this last section of Module C-1, we will briefly consider why chemical reactions occur. There are probably three major conditions affecting reactions. We will consider them one at a time.

FACTORS AFFECTING REACTIONS:

1. Activity of the elements.
2. Stability of the compounds formed.
3. Tendency of the reaction to reverse.

SLIDE #24

The activity of an element depends on its tendency to gain or lose electrons. The greater the ability of an element to lose or gain, the more active the element is.

Look at slide twenty-five. The elements in the first vertical column or Group I of the Periodic Table easily lose their single valence electron and therefore are very active. They are never found as free metals in nature but are always combined with other elements. As we progress toward the center of the Table, atoms must lose more valence

THE PERIODIC TABLE

SLIDE #25

electrons to lose their outer shell. This is more difficult; therefore, they become less active. As we approach the right-hand side of the chart, there is an increasing tendency for the elements to gain electrons to complete their valence shell. Group 7 requires only 1 electron to complete its outer shell. It is relatively easy to gain and hold one electron so these elements are active non-metals. Group 8 elements have a full valence shell and no charge, so they are inert (or non-reactive).

A second major consideration in whether or not reactions occur is the stability of the compounds formed by the reaction. If unstable compounds are formed, the reaction is not likely to go.

The stability of compounds depends largely on the amount of energy that is given off or absorbed as the compound is formed. Compounds with high negative heats of formation, that is, heat is given off or taken away as the compound forms, are stable. The reason is simple. For the compound to come apart, the heat given off during formation would have to be supplied if they were to part.

Advance to slide number twenty-six. If heat is given off the energy level of the elements in the products is lower than the reactants. The lower the energy level, the more heat that must be supplied to decompose the compound.

SEE PAGE 110A -- FOLLOWING

SLIDE #26

Conversely, if heat is absorbed in the formation of a compound, no energy is required to decompose the compound. Therefore, if the temperature is raised enough to activate the decomposition reaction, it goes spontaneously. A match head or a stick of dynamite are examples of materials which absorb heat in their formation. Explosives are generally unstable compounds with high positive heats of formation.

A third factor affecting chemical reactions is their tendency to reverse. All chemical reactions reverse to some degree. The ones that reverse very little are said to go to completion.

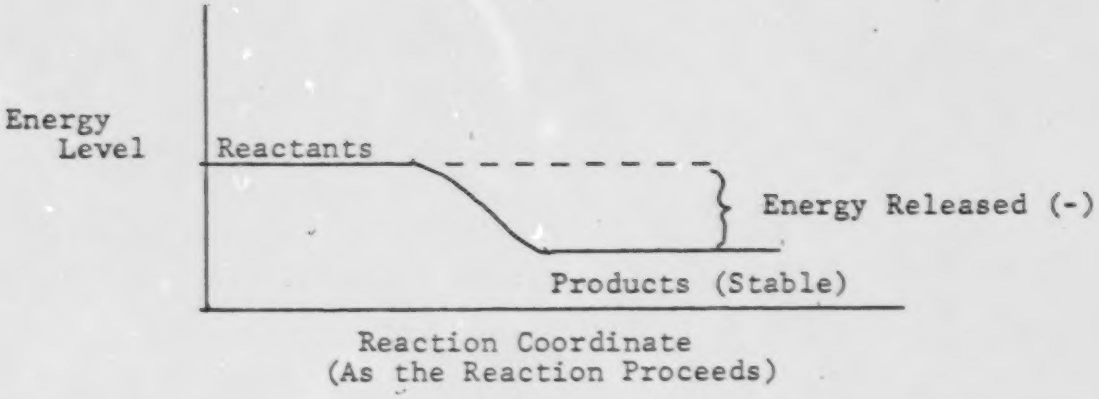
Look at slide number twenty-seven. Here is the reaction that occurs in an unopened coke bottle. Carbonic acid is

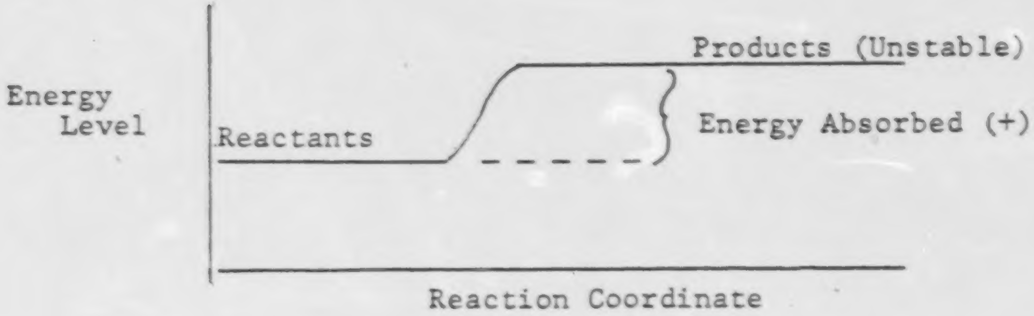
$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

Carbonic Acid

Equilibrium -- when opposing reactions occur at the same rate

SLIDE #27


Energy Level
Reactants
Energy Released (-)
Products (Stable)
Reaction Coordinate
(As the Reaction Proceeds)


Products (Unstable)
Energy Level
Energy Absorbed (+)
Reactants
Reaction Coordinate

SLIDE #26

constantly being formed and is constantly decomposing. As long as the top stays on the bottle, the rates of formation and decomposition remain the same and equal, therefore nothing appears to be happening. We say that a system such as this is in equilibrium. Note the definition of equilibrium on slide number twenty-seven.

Once the system is at equilibrium, it remains at equilibrium until conditions change. If, for example, pressure on the CO_2 - carbonic acid - system in the coke bottle is decreased by removing the cap, the reaction will go so that it will try to replace the escaping CO_2 until a new equilibrium point is reached. Hence, the bubbling when the top is removed.

As a result of studying this section, you should be able to name three factors affecting reactions and you should be able to state how each factor affects a reaction. Look at slides number twenty-eight and twenty-nine. Here you will find listed the concepts discussed in Module C-1 and your responsibility with regard to each one.

SEE PAGE 111A - FOLLOWING

SLIDE #28

SEE PAGE 111B - FOLLOWING

SLIDE #29

CONCEPT	YOUR RESPONSIBILITY
SECTION I	
Symbol	Be able to identify definitions
Formula	
Equation	
Valence	Explain relationship to electronic number
Combination #	
Write Formulas	Given combining #
SECTION II	
Law of Conservation of Mass	Identify statement or use principle
Balance Equations	Given Formulas
SECTION III	
Reaction Types	
Synthesis	Be able to identify
Decomposition	
Single Replacement	
Ion Exchange	

SLIDE #28

CONCEPT	YOUR RESPONSIBILITY
Oxidation	Be able to identify definition and use terms
Reduction	
Anode	
Cathode	
Anion	
Cation	
Electrolysis	
Emf Series	
Corrosion	Recognize an explanation in terms of electrochemical action
Cathodic Protection	Recognize explanation
Cells	Be able to label parts Be able to recognize the action at electrodes

SLIDE #29

MODULE C-1 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the MODULE C-1 examination for the first time. You may submit the problem set as many times as are needed in order to attain the 70% level.

The following pages in your text are relevant to MODULE C-1 as well as to the completion of the problem set. Those pages are: 45-46, 49, 53, 61-65, 113, 116, 132-133, 175, 179, 190-192, 197, 223, 234-236, 244-258, 260, 291-295.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown.

(Read Across)

Page	Problems
55	1
66	10
136	15
198	2, 6
241	3, 6
261	2

MODULE C-1 PROBLEM SET SOLUTIONS

Page Problem

55 (1) Given Sample mass = .1037g
0.0637g gold
compound contained
gold and chlorine

Percent by mass of chlorine = $\frac{\text{mass of chlorine}}{\text{mass of compound}}$ x 100

$$\begin{array}{rl} & .1037\text{g compound mass} \\ - & \underline{.0637\text{g gold}} \\ & .0400\text{g chlorine contained in compound} \end{array}$$

$\frac{.0400}{.1037}$ x 100 = % by mass of chlorine = 38.5%

66 (10) a. $3H_2(g) + 2N_2(g) \rightleftharpoons 2NH_3(g)$

b. $CaCl_2(ag) + Na_2CO_3(ag) \longrightarrow 2NaCl(ag) + CaCO_3(s)$

c. $2Al(OH)_3(s) \longrightarrow Al_2O_3(s) + 3H_2O(g)$

d. $B_2O_3(s) + 3H_2O \rightarrow 2H_3BO_3(ag)$

e. $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$

136 (15) 1 mole C_3H_8 = (3 x atomic weight of C) + (8 x atomic weight of H)
= (3 x 12.01 grams) + (8 x 1 gram)
= 36.03g + 8g
= 44.03g = 1 mole C_3H_8

531Kcal heat released for each mole of C_3H_8 which oxidized

250 grams of propane (C_3H_8) are oxidized or 5.7 moles

5.7 moles x 531Kcal = heat released

3026.7Kcal heat released

198 (2) In general, non-metals would have the higher first ionization potentials because they have a tendency to gain rather than loose electrons in filling their outer shells.

Page **Problem**

198 (6) The logic behind the stability of atoms with more than one Lewis structure is as follows:

a. The energy required to separate an electron from an atom is the ionization potential.

b. Once an electron is removed from an atom, the remaining positive ion has a greater positive charge on the nucleus than the remaining total negative charge produced by the electron cloud.'

c. The greater positive charge makes it more difficult to remove a second electron; therefore, the second ionization potential is always greater than the first.

241 (3) Ammonia is a weak electrolyte, that is, it does not produce much NH_4^+ or OH^- but a rather large amount of $NH_3(g)$.

241 (6) Dissolve them one at a time in H_2O and check their electrical conductivity. The species with the greater conductivity is the stronger acid.

261 (2) a. $\underset{4\ -2}{MnO_2(s)} + \underset{1-1}{4HCl(ag)} \longrightarrow \underset{2\ -1}{MnCl_2(ag)} + \underset{0}{Cl_2} + \underset{1-2}{2H_2O}$

Oxidation: chlorine -1 to 0 with the loss of 1 e^-

Reduction: manganese +4 to +2 with a gain of 2 e^-

b. $\underset{0}{3P(s)} + \underset{1\ 5-2}{5HNO_3(ag)} + \underset{1-2}{2H_2O} \longrightarrow \underset{2-2}{5NO(g)} + \underset{1\ 5-2}{3H_3PO_4(ag)}$

Oxidation: phosphorous 0 to +5 with a loss of 5 e^-

Reduction: nitrogen +5 to +2 with a gain of 3 e^-

c. $\underset{5-2}{2IO_3^-} + \underset{1-2}{6H_2O} \longrightarrow \underset{0}{I_2(s)} + \underset{-2\ 1}{12OH^-}$

Oxidation: none

Reduction: iodine +5 to 0 with a loss of 5 e^-

d. $\underset{0}{2Fe(s)} + \underset{1\ -2}{6H_3O^+} \longrightarrow \underset{0}{3H_2(g)} + \underset{3}{2Fe^{3+}} + \underset{1\ -2}{6H_2O}$

Oxidation: iron 0 to +3 with a loss of 3 e^-

Reduction: Hydrogen +1 to 0 with a gain of 1 e^-

Page Problem

261 (2) e. $2\underset{1}{H_2}\underset{-2}{S}(g) + \underset{4}{S}\underset{-2}{O_2}(g) \longrightarrow 3\underset{0}{S}(s) + 2\underset{1}{H_2}\underset{-2}{O}$

Oxidation: sulfur -2 to 0 with a loss of 2 e^-

Reduction: sulfur +4 to 0 with a gain of 4 e^-

f. $2\underset{0}{Na}(s) + \underset{0}{H_2}(g) \longrightarrow \underset{1}{Na}\underset{-1}{H}(s)$

Oxidation: sodium 0 to +1 with a loss of 1 e^-

Reduction: hydrogen 0 to -1 with a gain of 1 e^-

Name ______________________________

MODULE C1 - 1 EXAMINATION

1. Balance the following:

$$N_2H_4 \longrightarrow NH_3 + N_2$$

2. If the atomic weight of N = 23, H = 1, what is the molecular weight of the N_2H_4 in the balanced equation?

3. The electromotive series is a list of substances arranged according to their ability to:

4. In cathodic protection, the zinc on the hull of the ship wastes away before the hull or the screw because:

5. If the element oxygen is not necessary for the process of oxidation to take place, what then is oxidation?

6. There are three factors which influence a chemical reaction, they are:

   a. The ______________ of the products

   b. the ______________ of the reactants, and

   c. the ______________ of the reaction.

MODULE C1 - 1 EXAMINATION SOLUTION SET

1. $3N_2H_4 \longrightarrow 4NH_3 + N_2$

2. (6 x 23) + (12 x 1) = 150

3. Electronegativity is a measure of an atom's ability to attract and hold bonding electrons. The position in the electromotive series indicates relative ability to accomplish this task.

4. The zinc is more active than the metals which comprise the hull or the screw therefore, the zinc rather than the metals comprising the hull or screw corrodes first.

5. Oxidation is a reaction in which there is a loss of electrons or an increase in the oxidation number of an element to a more positive value.

6. a. Stability
   b. Electronegativity
   c. Reversibility

Name ______________________

MODULE C1 - 2 EXAMINATION

1. Balance the following equation:

$$C_4H_{10} + O_2 \longrightarrow CO_2 + H_2O$$

2. Complete the following chemical equations (examples of four types of reactions)

$H_2 + O_2 \longrightarrow$

$H_2O \longrightarrow$

$HCl + Zn \longrightarrow$

$NCL + NaOH \longrightarrow$

3. Define what is meant by the "electromotive series".

4. We put zinc plates on the hull of the ship to protect the hull and screw. Explain how this protection process works. Use the above definition in your answer.

5. If a chemical reaction is "exothermic" is energy lost or gained in the reaction?

6. Name the three essential components of an electrochemical cell.

a. ______________________

b. ______________________

c. ______________________

MODULE C1 - 2 EXAMINATION SOLUTION SET

1. $C_4H_{10} + 9O_2 \longrightarrow 4CO_2 + 10H_2O$

2. $H_2 + O_2 \longrightarrow H_2O$ Synthesis
   $H_2O \longrightarrow H_2 + O_2$ Decomposition
   $Zn + HCl \longrightarrow ZnCl_2 + H_2$ Single Replacement
   $HCl + NaOH \longrightarrow NaCl + H_2O$ Ion Exchange

3. Electronegativity is a measure of an atom's ability to attract and hold bonding electrons. The location of an atom in the EMF series indicates relative ability to accomplish this task.

4. The zinc is more active than the metals which comprise the hull or the screw therefore, the zinc rather than the metals comprising the hull or screw corrodes first.

5. A reaction in which heat is given off.

6. a. Anode
   b. Cathode
   c. Electrolyte

Name ______________________

MODULE C1 - 3 EXAMINATION

1. Define each of the following terms:

   a. Electrolysis

   b. Anion

   c. Cation

   d. Electrolyte

2. Balance the following equations:

   a. $NaOH(ag) + H_2S(g) \longrightarrow Na_2S(ag) + H_2O(l)$

   b. $Fe(s) + O_2(g) \longrightarrow Fe_2O_3(s)$

3. Why are some reactions called endothermic?

4. What are the factors which determine whether or not a chemical reaction will occur?

5. What type of a chemical reaction is that which occurs between air and a match after ignition?

MODULE C1 - 3 EXAMINATION SOLUTION SET

1. a. The producing of chemical charges by passage of an electric current through an electrolyte.

   b. The ion in an electrolyzed solution that migrates to the anode.

   c. The ion in an electrolytized solution that migrates to the cathode.

   d. A compound that conducts electricity when in solution or in the molten state.

2. a. $2NaOH(ag) + H_2S(g) \longrightarrow Na_2S(ag) + 2\ H_2O$

   b. $4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s)$

3. Because they require the addition of heat energy in order to happen.

4. Stability of the products, the reversibility of the reaction, electronegativies of the reactants.

5. Exothermic.

Name ________________________

MODULE C1 - 4 EXAMINATION

1. Balance the following equations:

   a. $FeS_2(s) + O_2(g) \longrightarrow Fe_2O_3(s) + SO_2(g)$

   b. $NH_3(g) + O_2(g) \longrightarrow NO_2(g) + H_2O(g)$

   c. $C_4H_{10} + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

2. Define the following terms:

   a. Oxidation

   b. Reduction

   c. Electrolyte

   d. EMF series

3. Zinc and steel are in contact on the hull of a ship in salt water; however, the zinc appears to corrode while the steel does not. Explain the phenomenon which is being observed.

4. Draw and label an electrochemical cell.

5. Give three examples of exothermic reactions.

P. 123

MODULE C1 - 4 EXAMINATION SOLUTION SET

1. a. $4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$

   b. $4NH_3 + 7O_2 \longrightarrow 4NO_2 + 6H_2O$

   c. $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$

2. a. A reaction in which there is a loss of electrons or an increase in oxidation number to a more positive value.

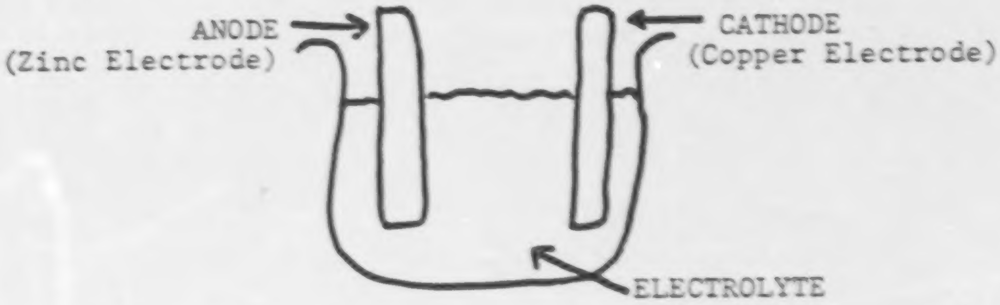
   b. A reaction in which there is a gain of electrons or a decrease in oxidation number to a less positive value.

   c. A compound which conducts electricity when in solution or in the molten state.

   d. A series in which elements are ordered according to their relative abilities to react.

3. The zinc is more active than the steel. Therefore, the zinc reacts or corrodes first, protecting the steel from corrosion.

4. Electrochemical cell:



5. Any chemical reaction which in the process of its conduct gives off heat.

Name ______________________________

MODULE C1 - 5 EXAMINATION

1. Define the following terms:

   a. Oxidation

   b. Reduction

   c. Electrolyte

   d. Anion

   e. Cation

   f. EMF series

   g. Exothermic reaction

   h. Endothermic reaction

2. Balance the following equations:

   a. $Al(s) + Cr_2O_3(s) \longrightarrow Al_2O_3(s) + Cr(s)$

   b. $NO(g) + O_2(g) \longrightarrow NO_2(g)$

   c. $K_2CO_3(ag) + Sr(NO_3)_2(ag) \longrightarrow KNO_3(ag) + SrCO_3$

3. In the following balanced equation:

   $$4H_2 + 2O_2 \longrightarrow 4H_2O$$

   if 101 grams of reactants are completely consumed, how many grams of product are formed and why?

MODULE C1 - 5 EXAMINATION SOLUTION SET

1. a. A reaction in which there is a loss of electrons or an increase in oxidation number to a more positive value.

   b. A reaction in which there is a gain of electrons or an increase in oxidation number.

   c. A compound which conducts electricity when in solution or in the molten state.

   d. Negative ions, ions which move to the anode in a cell.

   e. Positive ions, ions which move to the cathode in a cell.

   f. A series in which elements are ordered according to their relative abilities to react.

   g. A reaction which during its conduct, gives off heat.

   h. A reaction which requires heat in order to occur.

2. a. $2Al + Cr_2O_3 \longrightarrow Al_2O_3 + 2Cr$

   b. $2NO + O_2 \longrightarrow 2NO_2$

   c. $K_2CO_3 + Sr(NO_3)_2 \longrightarrow 2KNO_3 + SrCO_3$

3. 101, the Law of Conservation of Mass says that the mass of the products must equal the mass of the reactants if the reactants are totally consumed.

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Name ______________________________

MODULE C1 - 6 EXAMINATION

1. Draw and label an electrochemical cell.

2. After five years in the water, you find that your ship's wheel has just started to corrode. Explain why the corrosion has only just begun.

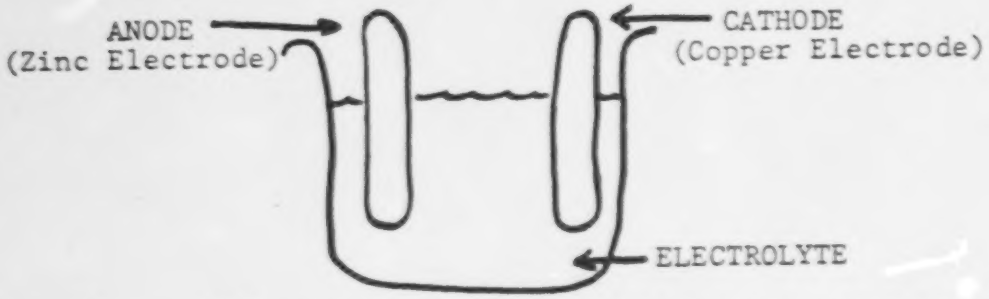
3. After pouring two chemicals together, you observe a large amount of heat to be radiating from the container. How can you account for this?

4. We see chemical reactions occuring everyday. What are the factors which determine whether or not a chemical reaction will occur?

5. We speak generally of four types of chemical reactions. What are these types?

MODULE C1 - 6 EXAMINATION SOLUTION SET

1. Electrochemical cell:


ANODE
(Zinc Electrode)
CATHODE
(Copper Electrode)
ELECTROLYTE

2. Because the zinc plates which were put on the hull are more reactive than the ship's wheel. They corrode first, protecting the other parts of the ship.

3. The reaction is exothermic.

4. Stability of the products, electronegativity of the reactants, reversibility of the reaction.

5. Synthesis, decomposition, single replacement, ion exchange.

Module C1
P. 128

Name ______________________________

MODULE C1 - 7 EXAMINATION

1. Name the types of reactions shown below:

   a. $A + B \longrightarrow AB$

   b. $AB \longrightarrow A + B$

2. Balance the following equations:

   a. $C_7H_{14}(g) \longrightarrow C_7H_8(g) + H_2(g)$

   b. $AgNO_3(ag) + Nal(ag) \longrightarrow Agl(s) + NaNO_3(ag)$

   c. $H_2 + O_2 \longrightarrow 12H_2O$

3. If you have a sample silver and chlorine whose mass is 0.2074 grams and the mass of the silver is 0.1274 grams, what is the percent by mass of chlorine?

4. Name three factors which must be taken into consideration when you are trying to decide whether or not a chemical reaction will occur.

5. What has the Law of Conservation of Matter to do with chemical reactions?

MODULE C1 - 7 EXAMINATION SOLUTION SET

1. a. Synthesis

   b. Decomposition

2. a. $C_7H_{14} \longrightarrow C_7H_8 + 3H_2$

   b. $AgNO_3 + Nal \longrightarrow Agl + NaNO_3$

   c. $12H_2 + 6O_2 \longrightarrow 12H_2O$

3. $$\begin{array}{r} .0274g \\ -.1274g \\ \hline .0800g \end{array} \qquad \frac{.0800}{.2074} \times 100 = \%Cl \text{ by mass} = 38.5\%$$

4. Stability of the products, electronegativity of the reactants, reversibility of the reaction.

5. The Law of Conservation of Matter suggests that if all of the reactants are consumed, the mass of products must be equivalent to the mass of the reactants.

Name ______________________________

MODULE C1 - 8 EXAMINATION

1. Describe a way in which the corrosion of ship's hulls may be minimized. Explain why the action you take will cause a decrease in corrosion.

2. Draw a model of an electromotive series and then discuss the drawing.

3. Draw an electrochemical cell and then label it.

4. Balance the following equations:

   a. $NaOH(ag) + H_2S(g) \longrightarrow Na_2S(ag) + H_2O(e)$

   b. $H_2 + O_2 \longrightarrow 24H_2O$

   c. $NO(g) + O_2(g) \longrightarrow NO_2(g)$

   d. $FeS_2(s) + O_2(g) \longrightarrow Fe_2O_3(s) + SO_2(g)$

5. Name the following types of reactions:

   a. $H_2 + O_2 \longrightarrow H_2O$

   b. $H_2O \longrightarrow H_2 + O_2$

MODULE C1 - 8 EXAMINATION SOLUTION SET

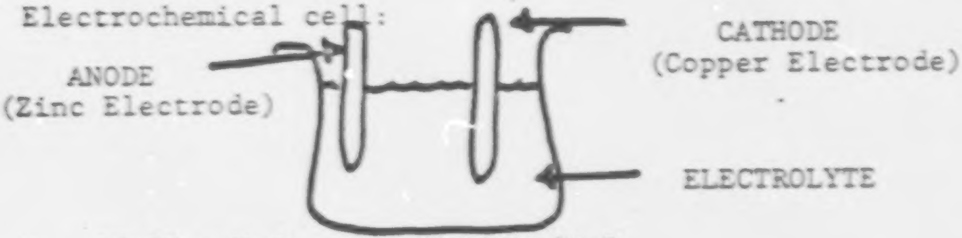
1. Attach zinc plates to the hull. The zinc plates are more reactive than the other metals and therefore will protect the others.

2.

ELEMENT	POTENTIAL (VOLTS)
Na	+2.71
Zn	+0.762
H	0.00
Cu	-0.345
Mn	-1.52

The series indicates an elements relative ability to gain or lose electrons. The more positive an element the more easily it gives up electrons. Conversely, the more negative an element, the greater its affinity for electrons.

3. Electrochemical cell:



4. a. $2NaOH + H_2S \longrightarrow Na_2S + 2H_2O$

   b. $24H_2 + 12O_2 \longrightarrow 24H_2O$

   c. $2NO + O_2 \longrightarrow 2NO_2$

   d. $4FeS + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$

5. a. Synthesis

   b. Decomposition

Name ______________________________

MODULE C1 - 9 EXAMINATION

1. Define the following terms:
   - a. Valence
   - b. Anion
   - c. Cation
   - d. Electrolyte

2. Balance the following equations:
   - a. $Al + Cr_2O_3 \longrightarrow Al_2O_3 + Cr$
   - b. $NO + O_2 \longrightarrow NO_2$
   - c. $K_2CO_3 + Sr(NO_3)_2 \longrightarrow KNO_3 + SrCO_3$
   - d. $AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$
   - e. $4H_2 + 2O_2 \longrightarrow H_2O$
   - f. $Fe + O2 \longrightarrow Fe_2O_3$
   - g. $C_4H_{10} + O_2 \longrightarrow CO2 + H_2O$

3. Describe the following reaction types:
   - a. Synthesis
   - b. Decomposition
   - c. Replacement
   - d. Ion exchange

MODULE C1 - 9 EXAMINATION SOLUTION SET

1. a. The number of electrons which is/are required in order to complete the outermost shell of an atom.

   b. A negative ion; ions which move to the anode of a cell.

   c. A positive ion; ions which move to the positive plate of a cell.

   d. A compound which conducts electricity when in solution or in the molten state.

2. a. $2Al + Cr_2O_3 \longrightarrow Al_2O_3 + 2Cr$

   b. $2NO + O_2 \longrightarrow 2NO_2$

   c. $K_2CO_3 + Sr(NO_3)_2 \longrightarrow 2KNO_3 + SrCO_3$

   d. $AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$

   e. $4H_2 + 2O_2 \longrightarrow 4H_2O$

   f. $4Fe + 3O_2 \longrightarrow 2Fe_2O_3$

   g. $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2$

3. a. A reaction in which two or more reactants are put together to form a compound.

   b. A reaction in which a compound is broken into two products.

   c. A reaction in which one species in a compound is replaced by another.

   d. A reaction involving charged species.

Name ______________________________

MODULE C1 - 10 EXAMINATION

1. Name three essential components of an electrochemical cell.

2. What is one difference between exothermic and endothermic reactions?

3. What factors determine whether or not a chemical reaction will occur?

4. What is an electromotive series and what is its relationship to chemical reactions?

5. Balance the following equation:

   $Al + Cr_2O_3 \longrightarrow Al_2O_3 + Cr$

6. Define the following terms:

   a. Anion

   b. Cation

7. Why will zinc blocks protect the hull of a ship from corrosion?

MODULE C1 - 10 EXAMINATION SOLUTION SET

1. Container; cathode, anode (electrodes); electrolytes.

2. An exothermic reaction gives off heat while an endothermic reaction requires heat in order to occur.

3. Stability of the products reversibility of the reaction, electronegativity of the reactants.

4. A series in which the elements are placed according to their relative abilities to react with one another.

5. $2Al + Cr_2O_3 \longrightarrow Al_2O_3 + 2Cr$

6.
   a. A negative ion: the ion which moves to the anode of a cell.

   b. A positive ion; the ion which moves to the cathode of a cell.

7. Because they are more reactive than the metals used in the ship's hull.

MODULE C-2 QUANTATIVE RELATIONSHIPS

Module C-2, Quantative Relationships, is the second module in the C series. The concepts of atomic weight, molecular weight, mole and stoichiometric calculations are presented herein. As a result of studying this module the student will be able to define all of the concepts listed above, and make the various calculations inferred in the concept names.

In Module C-2 you will explore the calculation procedures of some quantative relationships in chemistry. The quantaties of air required for combustion, for example, can be calculated if one knows how much fuel is to be burned.

Advance your slide carrousel to slide number one. The Periodic Table gives, among other things, the relative weights of atoms. You may have to look at the key to see where the atomic weights are located. You should also have a Periodic Table in your notebook. It will be easier to refer to that one than the one on the slide.

THE PERIODIC TABLE

SLIDE #1

The basis of the atomic weight system is the isotope of carbon with 6 protons and 6 neutrons. It's weight has been arbitrarily set at 12.00 atomic mass units. The weights of the other elements are relative to carbon 12. For example, hydrogen atoms weight about 1/12 as much as carbon atoms; therefore, have a weight of approximately 1 amu (atomic mass unit).

Look at slide number two. To find the weight of a molecule in atomic mass units, the weights of the atoms must be added.

Molecular weight of sulfuric acid

Formula: H_2SO_4

2H at 1 amu each = 2 amu

1S at 32 amu ea. = 32 amu

4O at 16 amu ea. = 64 amu

Molecular weight = Total = 98 amu
Atomic weights are from Periodic Chart, rounded off to the nearest whole number.

SLIDE #2

Sulfuric acid (H_2SO_4) molecules contain 2 atoms of hydrogen (H), one atom of sulfur (S), and 4 atoms of oxygen (O). Their weights are totaled as shown in slide number two. If you don't already know how to find a molecular weight, you should study the slide for a few minutes until it makes sense; that is, until you understand from whence each number comes.

Find the molecular weight of:

$NaOH$

KNO_3

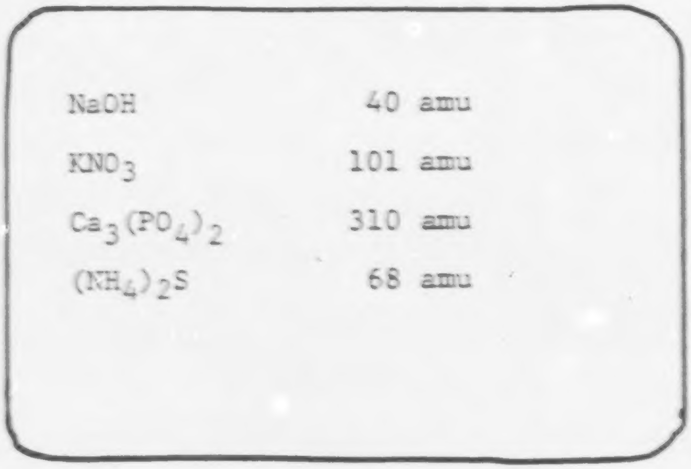
$Ca_3(PO_4)_2$

$(NH_4)_2S$

SLIDE #3

Advance to slide number three. For practice try to find the molecular weights of the molecules listed on slide number three. Round atomic weights off to the nearest whole number.

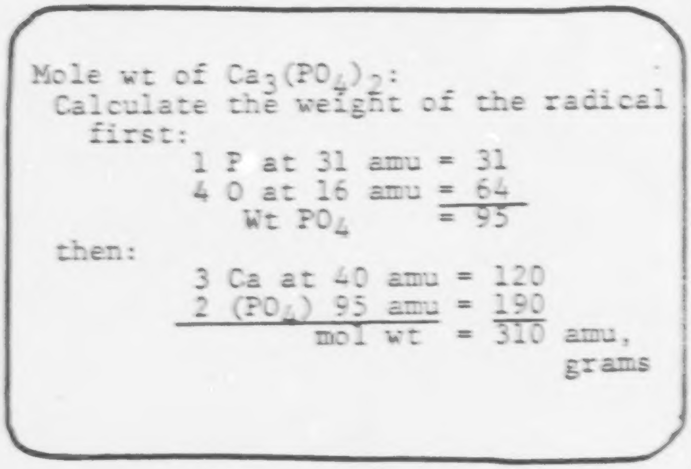
Look at slide number four. The molecular weights from the molecules on slide number three are given here. The most complex one is calcium phosphate $Ca_3(PO_4)_2$. Your answers should match those given on slide number four.



NaOH	40 amu
KNO_3	101 amu
$Ca_3(PO_4)_2$	310 amu
$(NH_4)_2S$	68 amu

SLIDE #4

Look at slide number five. Here you find a solution to calcium phosphate $Ca_3(PO_4)_2$.



Mole wt of $Ca_3(PO_4)_2$:
Calculate the weight of the radical first:

$$\begin{array}{rl} 1\ P \text{ at } 31 \text{ amu} & = 31 \\ 4\ O \text{ at } 16 \text{ amu} & = \underline{64} \\ \text{Wt } PO_4 & = 95 \end{array}$$

then:

$$\begin{array}{rl} 3\ Ca \text{ at } 40 \text{ amu} & = 120 \\ \underline{2\ (PO_4)\ 95 \text{ amu}} & = \underline{190} \\ \text{mol wt} & = 310 \text{ amu, grams} \end{array}$$

SLIDE #5

Since the weights of atoms are relative to carbon whose weight is arbitrarily set at 12, any units can be applied to these numbers. It is convenient to use the gram in the laboratory as the unit of weight. The molecular weight in grams is called a gram mole which means gram molecular weight. Perhaps you should copy that definition in your notebook.

The atomic weight of carbon is 12. Therefore the weight of one gram mole of carbon is 12 grams. The mole of an element is sometimes called a gram atom. The molecular weight of sodium hydroxide is 40. Therefore 40 grams of sodium hydroxide is one mole. 20 grams of sodium hydroxide is ½ mole. Again, the reason that we can shift from amu units to grams units or any other units is that the amu units are relative weights. One hydrogen atom weighs 1/12 as much as 1 carbon atom. Therefore, 1 gram of hydrogen contains the same number of atoms as 12 grams of carbon.

Advance your carrousel to slide number six. A balanced equation tells us the numbers of molecules that react with each other. The equation in slide number six tells us that 2 molecules of hydrogen are required to react with each molecule of oxygen to produce water. Notice that the lack of a coefficient before a formula implies that the coefficient is one.

Balanced equation for the formation of water:

$$2H_2 + O_2 \rightarrow 2H_2O$$

SLIDE #6

Look at slide number seven. The first equation tells us that 2 hydrochloric acid (HCl) molecules are required to react with one molecule of calcium carbonate ($CaCO_3$) to yield one molecule of calcium chloride ($CaCl_2$), one water molecule (H_2O) and one

1. $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

2. $\underset{\text{ethane}}{2C_2H_6} + 7O_2 \rightarrow 4CO_2 + 6H_2O$

SLIDE #7

carbon dioxide molecule (CO_2).

What does equation number two on slide seven say in words? Write it out.

Equation #2 tells us that 2 molecules, or moles, of ethane (C_2H_6) react with 7 moles of oxygen (O) to yield 4 moles of carbon dioxide (CO_2) and 6 moles of water (H_2O).

The ratio of moles of ethane (C_2H_6) to moles of oxygen (O) is 2 to 7. What is the ratio of moles of oxygen to carbon dioxide (CO_2) produced? If you said 7 to 4 you were correct. How about the ratio of moles of ethane (C_2H_6) to moles of water (H_2O)? You should have gotten a ratio of 1 to 3.

Look at slide number eight. Suppose you have 100 grams of iron ore. How much iron (Fe) can be derived from it?

See Page 140A -- Following

SLIDE #8

The equation tells you that you get 2 moles of iron (Fe) from each mole of iron oxide (Fe_2O_3). If you knew how many moles of ore you had, you would know that you had twice as many moles of iron (Fe). However,

$$\underset{\text{iron ore}}{2Fe_2O_3} + 3C \longrightarrow 3CO_2 + \underset{\text{iron}}{4Fe}$$

1. Mole ratio Fe to Fe_2O_3 = 4/2 = 2/1

2. Mole wt Fe_2O_3: 2 Fe @ 56 amu = 112
   3 O @ 16 = 48
   mol wt = 160

3. Number of moles Fe_2O_3 = 100/160 = 5/8

4. But moles Fe = 2 times moles of Fe_2O_3

5. Therefore:
   Number of moles Fe = 2(5/8) = 10/8 = 1¼

6. But 1 mole Fe = 56 grams

   Therefore 1¼ moles Fe = 1¼(56) = 70 grams

SLIDE #8

can you calculate the number of moles of iron ore. The molecular weight of Fe_2O_3 is 160, or 160 grams; therefore 100 grams of Fe_2O_3 equals 5/8 of of a molecular weight, or 5/8 mole. Since the ratio of moles of Fe to moles of Fe_2O_3 is 2:1, (from step one) there are 1¼ moles of Fe. Since each mole of Fe weighs 56 grams, 1¼ moles of Fe must weight 70 grams.

You can, therefore, expect to get 70 grams of iron (Fe) from each 100 grams of ore. Or, since these are ratios and any unit may be applied, you might expect to get 70 tons of iron (Fe) from each 100 tons of ore, and so on.

If this process did not make sense to you, go back through it, working out each step on a piece of paper.

When you get to where the process makes some sense, calculate the number of grams of carbon (C) required for every 100 grams of ore which are reduced.

See Page 141A - Following

SLIDE #9

Advance to slide number nine. Here, the carbon problem has been worked out. If you still do not

$$2Fe_2O_3 + 3C \longrightarrow 3CO_2 + 4Fe$$

1. Mole ratio C/Fe_2O_3 = 3/2
2. Mole wt. Fe_2O_3: 2 Fe @ 56 = 112 amu
   3 O @ 16 = 48 amu
   total = 160 = mol wt
3. Moles Fe_2O_3 = 100 grams/1609 grams per mole
   = 5/8 mole
4. But moles C = 3/2(moles Fe_2O_3) = 3/2(5/8) = 15/16
5. But 1 mole C = 12 grams
6. Therefore: 15/16 moles C = 15/16(12 9/mol)
   = 45/4 = 11¼ grams

SLIDE #9

understand how to do the calculations, consult an instructor; otherwise, continue.

When gases are involved, it is of some interest to determine volumes. The volume can be determined from the number of moles.

Empirically, each gram mole of a gas occupies 22.4 liters at standard conditions. Standard conditions are 0 degrees centigrade and 1 atmosphere of pressure. Some standard condition is needed to compare gas volumes because gas volumes vary with temperture and pressure.

Look at slide number ten. Suppose, in the problem with which you have been working, you want to know the volume of carbon dioxide (CO_2) released when 100 grams of iron ore are reduced.

$2Fe_2O_3 + 3O_2 \longrightarrow 3CO_2 + 4Fe$

1. Mole ratio $CO_2/Fe_2O_3 = 3/2$
2. Moles Fe_2O_3 in 100g = 5/8 (slide 8)
3. Moles $CO_2 = 3/2(5/8) = 15/16$
4. Volume CO_2 at Standard Conditions:

$V = (15/16 \text{ moles } CO_2)(22.4 \text{ lites/mol})$

$= 21 \text{ 1}$

SLIDE #10

The ratio of moles of CO_2 to Fe_2O_3 is 3/2. You know that there are 5/8 moles of Fe_2O_3. The number of moles of CO_2 is 3/2 times the number of moles of Fe_2O_3, or 15/16 moles. Each mole of a gas occupies 22.4 liters at standard conditions. Therefore, the volume of CO_2 is 15/16 of 22.4, or 21 liters. If you understand this, go on. If not, work out each step on a sheet of notebook paper.

Look at slide number eleven. Suppose that you have one lb mole of Number 2 fuel oil and that its average molecular formula is $C_{16}H_{34}$. What volume of oxygen is required to burn 1 lb of fuel oil if one lb mole of oxygen occupies 359 cubic feet of space? See if you can solve the problem.

$2C_{16}H_{34} + 49O_2 \rightarrow 32CO_2 + 34H_2O$
#2 fuel

1 lb mole occupies 359 cubic ft @ S.C.

SLIDE #11

Advance to slide number twelve. The fuel oil problem is worked out there for you. (Compare your methods and answer with those used in the slide solution.)

See Page 143A - Following

SLIDE #12

If you did not get the answer and don't see how to get it, go back to the CO_2 volume calculation and study it again.

$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$ vapor
propane

Given: 10 liters propane

Then: vol O_2 = 5/1 x 10 = 50 l
vol CO_2 = 3/1 x 10 = 30 l
vol $H_2O_{(v)}$ = 4/1 x 10 = 40 l

SLIDE #13

Look at slide number thirteen. Volume-volume relationships are easy to calculate since equal volumes of gases contain equal numbers of molecules or moles. The volume ratios among gaseous reactants and their

$$2C_{16}H_{34} + 49O_2 \longrightarrow 32CO_2 + 34H_2O$$

1. Mole ratio O_2/fuel = 49/2

2. Mole wt. fuel: 16 C @ 12 ea = 192
   34 H @ 1 ea = 34
   Mole wt.= 226

3. Moles of fuel = 1 lb/226 lbs/mole
   = .00443 moles

4. Since moles O_2 = (mole ratio)(moles fuel)
   O_2 = (49/2)(.00443)
   = .1085 moles

5. Volume O_2 = (.1085 moles)(359 cu ft/mole)
   = 39 cu ft

SLIDE #12

products are simply the mole ratios.

The volume ratios are simply the coefficient ratios. Look at the slide until you see the method.

Look at slide number fourteen. Butane (C_4H_{10}) burns to form carbon dioxide (CO_2) and water (H_2O) vapor. Given 10 milliliters of butane (C_4H_{10}), find the volume of oxygen (O), CO_2, and water vapor involved in this chemical reaction.

$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

Butane

SLIDE #14

Look at slide number fifteen. Here you will find a solution to the problem presented above. Compare your answer to that given on the slide.

$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O_{(v)}$

Given 10 milliliters butane:

Vol O_2 = 13/2 x 10 ml = 65 ml

Vol CO_2 = 8/2 x 10 ml = 40 ml

Vol $H_2O_{(vap)}$ = 10/2 x 10 ml = 50 ml

SLIDE #15

Advance to slide number sixteen. As a result of studying this module, you should be able to calculate molecular weights, and solve molecular weight and volume problems.

OBJECTIVES OF MODULE C2

You should be able to:

1. Calculate molecular weight.
2. Solve problems given weight, weight required.
3. Solve problems given weight, volume required.
4. Solve problems given volume, volume required.

SLIDE #16

MODULE C-2 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70%, prior to taking the MODULE C-2 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE C-2 as well as to the completion of the problem set. Those pages are: 34-38, 41, 48, 49, 50-53, 119-134, 210-211, and inside of the back cover.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown. (Read across)

Page	Problems
43	8, 9, 12, 13
55	4
56	9, 12, 13
136	14
218	5

MODULE C-2 PROBLEM SET SOLUTIONS

Page Problem

43 (8) 1 gram mole Al = 26.98g Au

$$\text{g moles Al} = \frac{50.0\text{g}}{26.98\text{g}}$$

$$= 1.9$$

1 gram mole Au = 196.96g Au

1.9g moles Au = 1.9 x 196.96

$$= 374.224\text{g}$$

There are the same number of atoms in 50.0g Al as there are in 374.224g Au (answer is approximate).

43 (9) 1 gram mole C = 12.01g

1 mole contains 6.02×10^{23} atoms

$$\text{Mass of one atom C} = \frac{12.01\text{g}}{6.02 \times 10^{23} \text{ atoms}}$$
$$= 1.99 \times 10^{-23}\text{g/atom}$$

1 g mole P = 30.97g

$$\text{Mass of one atom P} = \frac{30.97\text{g}}{6.02 \times 10^{23} \text{ atoms}}$$

$$= 5.15 \times 10^{-23}\text{g/atom}$$

1 g mole Hg = 200.59g

$$\text{Mass of one atom Hg} = \frac{200.59\text{g}}{6.02 \times 10^{23} \text{ atoms}}$$
$$= 33.2 \times 10^{-23}\text{g/atom}$$

43 (12) An amu is an abbreviation for atomic mass units

1 atom of Mg = 24.3 amu

1 mole Mg = 24.3g

1 mole Mg contains 6.02×10^{23} atoms

? amu in 24.3g Mg = 24.3g x 6.02×10^{23} atoms

$$= 1.46 \times 10^{25} \text{ amu/24.3g Mg}$$

Page **Problem**

43 (13) $D = M/V$ $V = M/D$

1 mole Ti = 47.90g Density of Ti = 4.50g/ml

Volume of 1 mole of Ti = $\frac{47.90g}{4.50g/ml}$ = 10.4 ml

1 mole Ti = 6.02×10^{23} atoms

Volume of 1 atom of Ti = $\frac{10.4 \text{ ml}}{6.02 \times 10^{23} \text{ atoms}}$

= 1.7×10^{-23} ml/atom

55 (4) a. 65.38g/mole + 32.064g/mole = 97.444g/mole

b. (4 x 12.01g/mole) + (8 x 1g/mole) = 56.04g/mole

c. 54.93g/mole + (2 x 15.99g/mole) = 86.91g/mole

d. 40.08g/mole + (2 x 12.01g/mole = 64.1g/mole

e. 40.08g/mole + 12.01g/mole + (3 x 15.99g/mole)

= 100.06g/mole

56 (9) a. formula wt. H_2O = (2 x 1g/mole) + 15.99g/mole
= 17.99g/mole

grams in 12 moles H_2O = 12 x 17.99 = 215.88 grams

b. formula wt. CO = 12.01g/moles + 15.99g/mole
= 28.00g/mole

grams in 500 moles CO = 500 x 28 = 1.4×10^4 grams

c. formula wt. KNO_3 = 39.09g/moles + 14g/mole
+ (3 x 15.99g/mole) = 101.06 g/mole

grams in 3 moles KNO_3 = 3 x 101.06 = 303.18 grams

56 (12) 1 gram mole P = 30.97 grams

moles in 150g P = $\frac{150 g}{30.97g}$ = 4.8 moles

1 mole P = 6.02×10^{23} atoms

atoms in 4.8 moles P = $4.8 \times 6.02 \times 10^{23}$ atoms

= 2.8896×10^{24} atoms

Page	Problem	
56	(13)	formula wt. $O_3 = 3 \times 15.99 g/mole = 47.97 g/mole$
136	(14)	a. $2H_2(g) + O_2(g) \longrightarrow 2H_2O + 116Kcal$ b. $C(s) + 2S(s) + 28.7Kcal \longrightarrow CS_2(g)$
218	(5)	a. 780 ml 380 ml b. 205 ml 195 ml c. 78.1 ml 2.42 l d. 0.160 M 990 ml

Name ______________________________

MODULE C2 - 1 EXAMINATION

1. Define atomic weight and explain the basis for an element's atomic weight.

2. Define molecular weight and explain the basis for a molecule's molecular weight.

3. How many grams are needed to make the following: (You may use a Periodic Table)

   1 mole of H_2SO_4 ______________________

   3 moles of H_2O ______________________

   9 moles of NaOH ______________________

4. How many moles of hydrogen (H_2) are in each of the following:

   100 grams of H_2O ______________________

   30 grams of NaOH ______________________

   100 grams of HCl ______________________

5. Balance each of the following reaction equations:

   a. $H_2O_2 \longrightarrow O_2 + H_2O$

   b. $NH_4NO_3 \longrightarrow H_2O + N_2O$

   c. $C_6H_6 + O_2 \longrightarrow CO_2 + H_2O$

6. $C_2H_5OH + O_2 \longrightarrow 2CO_2 + 3H_2O$

   a. State the equation in terms of moles.

   b. If two grams of alcohol are burned, what weight of water will be produced?

   c. If two grams of alcohol are burned, how many liters of carbon dioxide will be produced?

   d. One half mole of oxygen will produce how many grams of carbon dioxide?

MODULE C2 - 1 EXAMINATION SOLUTION SET

1. Atomic weight of an atom is the atom expressed in atomic mass units. Its weight is relative to the most common isotope of carbon which is 12 atomic mass units.

2. Molecular weight is the sum of the mass of all the atoms that compose a molecule expressed in atomic mass units.

3. a. 1 mole H_2SO_4 = (2xH) + S + (4x0)
= (2x1) + 32.064 + (4 x 15.99)g
= 2g + 32.064g + 63.96g
= 98.024g

b. 3 moles H_2O = (6 x H) + (3 x 0)
= (6 x 1) + (3 x 15.99)
= 6g + 47.97g
= 53.97g

c. 9 moles NaOH = (9 x Na) + (9 x 0) + (9 x H)
= (9x 22.98) + (9 x 15.99) + (9 x 1)
= 206.82g + 144.01g + 9g
= 359.83g

4. a. 100gH_2O
1 mole H_2O = 18g
2/18 x 100 = mass of H in 100g H_2O
= 11.11gH
1 mole H = 1g
11.11gH = 11.11 moles H

b. 30g NaOH
1 mole NaOH = 39.97g
1/39.97 x 30 = mass of H in 30g NaOH
= 3/4gH
3/4gH = 3/4 mole H

c. 100g HCl
1 mole HCl = 36.45g
1/36.45 x 100 = mass of H in 100g HCl
= 2.74gH
2.74gH = 2.74 moles H

5. a. $2H_2O_2 \rightarrow O_2 + 2H_2O$

b. $NH_4NO_3 \rightarrow 2H_2O + N_2O$

c. $2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O$

6. a. 1 mole C_2H_5OH + moles oxygen → 2 moles CO_2 + 3 moles H_2O

b. 1 mole C_2H_5OH = 46g
1 mole H_2O = 18g

burning one mole of alcohol produces 3 moles of water; therefore, burning 2g of alcohol will produce 2.46 x 54g H_2O

= 2.5g H_2O produced

c. 1 mole CO_2 = 22.4 liters

burning 1 mole of alcohol produces 2 moles of CO_2 or 44.8 liters

2.46 x 44.8 = CO_2 produced = 1.95 liters produced

d. 1 mole of CO_2 or 44g of CO_2

Name ______________________

MODULE C2 - 2 EXAMINATION

GIVEN THE FOLLOWING ATOMIC WEIGHTS:

C = 12, O = 16, N = 14, Na = 23, H = 1, S = 32, Fe = 56

1. What would be the weight (in grams) of:

   a. one mole of H_2SO_4 ______________________

   b. three moles of NaOH ______________________

   c. .5 moles of H_2O ______________________

2. a. If I have 358 grams of C_3H_8, how many moles of it do I have?

   ____

   b. If I have 5,000 grams of H_2SO_4 how many moles of it do I have? ______________________

3. Hydrogen peroxide reduces to water and free oxygen according to the following:

$$H_2O_2 \longrightarrow O_2 + H_2O$$

   a. If I start with 100 grams of hydrogen peroxide, how many grams of water do I get?

   b. If I start with 500 grams of hydrogen peroxide, what volume of oxygen gas is released?

   c. If I release 400 liters of O_2, what weight of water is generated?

MODULE C2 - 2 EXAMINATION SOLUTION SET

1. a. one mole H_2SO_4 = 2g + 32g + (4 x 16)g
= 34 + 64g
= 98g

b. three moles NaOH = 3(23g + 16g + 1g)
= 69g + 48g +3g
= 120g

c. 1 mole H_2O = 18g
.5 mole = 18g/2 = 9g

2. a. 1 mole C_3H_8 = (3 x 12) + (8 x 1)
= 48g + 8g
= 56g

? moles in 358g = 358/56 = 6.4 moles

b. 1 mole H_2SO_4 = 98g

? moles in 5000g = 5000/98 = 52 moles

3. a. The balanced equation is $6H_2O_2 \longrightarrow 3O_2 + 6H_2O$
which means that the reduction of 6 moles of H_2O_2 produces
6 moles of oxygen and 6 moles of water

1 mole H_2O_2 = 34g
1 mole O = 16g
? moles H_2O_2 = 100g
100/34 = g H_2O_2 = 2.9 mole H_2O_2

Therefore, 2.9 moles of oxygen will be produced. It follows that 2.9 x 16g of oxygen will be released or 46.4g.

b. 500g H_2O_2 = 500/34 moles H_2O_2
= 14.5 moles

1 mole of oxygen is released for every mole of H_2O_2

Volume of oxygen = 14.5 x 22.5 liters = 326.25 liters

c. For every 2 moles of oxygen, one mole of water is generated.
1 mole of oxygen = 16g
? moles of oxygen = 400/16 = 25 moles
moles of H_2O generated = 25/2 = 12.5 moles
1 mole of H_2O = 18g
weight H_2O generated = 12.5 x 18g = 22.5g

Name ______________________

MODULE C2 - 3 EXAMINATION

GIVEN THE FOLLOWING ATOMIC WEIGHTS:

C = 12, O = 16, N = 14, H = 1

1. I am given 1,000 grams of fuel. How many liters of CO_2 are formed and what weight of water is formed if the fuel burns completely?

$$C_4H_{10} + O_2 \longrightarrow CO_2 + H_2O$$

You may leave your answer implied, i.e. in brackets ( ) ( ) ( ) =

2. In the following reaction hydrazine decomposes to form ammonia and nitrogen. If 500 liters of nitrogen were formed, how many grams of hydrazine were decomposed?

$$N_2H_4 \longrightarrow NH_3 + N_2$$

MODULE C2 - 3 EXAMINATION SOLUTION SET

1. The balanced equation is $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$

   1 mole C_4H_{10} = 58g and for every 1 mole of C_4H_{10} that is burned, 4 moles of CO_2 and 5 moles of H_2O are produced.

   1 mole CO_2 = 22.4 liters
   1 mole H_2O = 18g

   ? moles C_4H_{10} = 1000g C_4H_{10}
   = 1000/54
   = 18.4 moles C_4H_{10}

   Therefore, 22.4 x 5 x 18.4 liters CO_2 is produced or 2060.8 liters CO_2 and 5 x 18 x 18.4g H_2O is produced or 1656g H_2O

2. The balanced equation is $3N_2H_4 \longrightarrow 4NH_3 + 2N_2$

   Therefore, for every mole of N_2H_4 which is decomposed, 1-1/3 moles of nitrogen is formed.

   1 mole of nitrogen = 22.4 liters nitrogen
   ? moles N = 500 liters
   = 500^1/22.4 liters
   = 22.3 moles

   Number of moles of N_2H_4 decomposed = 3/4 number of moles of nitrogen produced.

   moles of N_2H_4 = 3/4 x 22.3 moles = 16.8 moles

   1 mole N_2H_2= 30g; therefore, gN_2H_2decomposed = 16.8 x 30 = 504.0g

Name ______________________________

MODULE C2 - 4 EXAMINATION

GIVEN THE FOLLOWING:

N = 14 amu, H = 1 amu, O = 16 amu

1. $NH_3 + O_2 \longrightarrow H_2O + NO$

   a. If I give you 100 grams of NH_3, what weight of H_2O is formed?

   b. If I use 500 liters of O_2, what weight of NO is formed?

   c. If I produce 500 liters of NO, how many liters of O_2 were consumed?

2. If I have 500 grams of hydrazine (N_2H_4), how many moles of it do I have?

3. If I have 500 liters of ammonia (NH_3), how much does it weigh?

MODULE C2 - 4 EXAMINATION SOLUTION SET

1. The balanced equation is $4NH_3 + 5O_2 \rightarrow 6H_2O + 4NO$

   a. For every mole of NH_3 that is burned, 1½ moles of H_2O is produced

   1 mole NH_3 = 17g
   1 mole H_2O = 18g

   ? moles in 100g NH_3 = 100/17 = 5.88 moles

   weight of H_2O produced = 18g x 1½ x 5.88 = 158.76g

   b. For every mole of oxygen used, 2/5 mole NO is produced or for every mole of O_2 consumed, 4/5 mole of NO is produced.

   1 mole O_2 = 22.4 liters

   ? moles in 500 liters O_2 = 500/22.4 = 22.3 moles O_2

   1 mole NO = 30g
   weight NO produced = 4/5 x 22.3 x 30 = 535.2g

   c. For every mole of NO produced, 5/4 mole of O_2 must be consumed.

   500 liters NO = 500/22.4 moles NO = 22.3 moles; therefore,
   moles of O_2 consumed = 5/4 x 22.3 = 27.85 moles

   liters of O_2 consumed = 27.85 x 22.4 = 623.84 liters

2. 1 mole of N_2H_4 = 32g
   500g of N_2H_4 = 500g/ 32g moles of N_2H_4 = 15.6 moles

3. 1 mole of NH_3 = 17g

   500 liters NH_3 = 22.3 moles
   weight NH3 = 22.3 x 17g = 379.1g

Name ____________________

MODULE C2 - 5 EXAMINATION

GIVEN THE FOLLOWING ATOMIC WEIGHTS:

H = 1, O = 16, C = 12, S = 32, N = 14

1. State the Law of Conservation of Mass (from C-1).

2. Balance this equation (an application of the Law).

$$C_4H_{10} + O_2 \text{ ----- } CO_2 + H_2O$$

3. In the above reaction, if I give you 100 grams of fuel to burn, how many grams of water would be formed? You may leave your answer with the arithmetic implied (brackets) rather than worked out.

4. In the above reaction, if 100 liters of carbon dioxide are formed, how many grams of fuel were burned?

5. In the above reaction, if 200 liters of oxygen are used, how many liters of CO_2 are formed?

6. How many grams of water are there in ten moles of water?

7. How many moles of CO_2 are there in 500 grams of CO_2?

8. How many moles of O_2 are there in 500 liters of O_2?

9. How many moles of CO_2 are there in 500 liters of CO_2?

MODULE C2 - 5 EXAMINATION SOLUTION SET

1. The Law of Conservation of Mass states that in a reaction mass is neither created nor destroyed.

2. $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$

3. 1 mole C_4H_{10} = 58g and for every mole of C_4H_{10} that is burned, 5 moles H_2O are produced.

   1 mole H_2O = 18g

   100g C_4H_{10} = 100g/58g moles C_4H_{10} = 1.7 moles

   Mass of H_2O produced = 1.7 x 5 x 18g = 153.0g

4. For every mole of C_4H_{10} which is burned, 4 moles of CO_2 are produced.

   moles of CO_2 produced = 100l/22.4l = 4.4 moles

5. For every mole of O_2 used 8/13 mole of CO_2 is produced and the same per liter relationship follows. Therefore, 8/13 x 200 liters of CO_2 will be formed or 123 liters.

6. 1 mole of H_2O is 18 grams

   10 moles of H_2O = 10 x 18g = 180g

7. 1 mole of CO_2 = 44g

   ? moles in 500g CO_2 = 500g/44g = 11.3g

8. 1 mole O_2 = 22.4 liters

   ? moles O_2 in 500 liters = 500l/22.4l = 22.3 moles

9. 22.3 moles

Name ______________________

MODULE C2 - 6 EXAMINATION

1. What is the atomic weight of an element?

2. What is the molecular weight of a substance?

3. Give the Atomic or Molecular weights for the following. (You may use a Periodic Table):

   H_2SO_4 ________________

   NaOH ________________

   $CaCO_3$ ________________

   HCl ________________

   H_2 ________________

4. Given: $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

   a. If 2 grams of propane are burned, what weight of CO_2 will be produced?

   b. Two moles of propane will combine with now many grams of oxygen?

   c. How many moles of propane will produce one mole of water?

Continued . . .

5. How many moles are there in:

   a. 90 grams of H_2O

   b. 22 grams of CO_2

   c. 45 grams of $C_6H_{12}O_6$

6. Given: $CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$

   a. How many moles of carbon dioxide are used to produce 10 moles of oxygen?

   b. What is the ratio of moles of carbon dioxide to moles of water used to produce one mole of $C_6H_{12}O_6$?

   c. What volume of CO_2 is used to produce one mole of $C_6H_{12}O_6$ if one mole of CO_2 occupied 2 liters of space?

MODULE C2 - 6 EXAMINATION SOLUTION SET

1. Atomic weight is the mass of an atom expressed in atomic mass units.

2. Molecular weight is the sum of the masses of all the atoms that comprise a molecule expressed in atomic mass units.

3.
   a. H_2SO_4 = 98amu
   b. NaOH = 40 amu
   c. $CaCO_3$ = 100 amu
   d. HCl = 36.453 amu
   e. H_2 = 2 amu

4. a. For every mole of C_3H_8 that is burned 3 moles of CO_2 are produced.

   1 mole of C_3H_8 = 44g

   2g of C_3H_8 = 2g/44g moles = 1/22 mole

   Therefore, burning 1/22 mole of C_3H_8 will produce 3 x 1/22 mole of CO_2 or 3/22 moles.

   1 mole of CO_2 = 44g

   weight of CO_2 produced = 3/22 x 44g = 6g

   b. Since burning one mole of C_3H_8 requires 5 moles of O_2, burning 2 moles of C_3H_8 will require 10 moles of O_2.

   c. Since burning one mole of C_3H_8 produces 4 moles of H_2O, burning 1/4 mole of C_3H_8 will produce 1 mole of H_2O.

5. a. 1 mole of H_2O = 18g
   moles of H_2O in 90g = 90g/18g = 5 moles

   b. 1 mole of CO_2 = 44g
   Therefore, 22g of CO_2 = 1/2 mole

   c. 1 mole of $C_6H_{12}O_6$ = 180g
   Therefore, 45g of $C_6H_{12}O_6$ = 1/4 mole

6. The balanced equation is $6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$

   a. Since for every mole of CO_2 used, one mole of O_2 is produced, 10 moles of CO_2 will produce 10 moles of O_2

   b. The ratio of moles of carbon dioxide to moles of water used to produce one mole of $C_6H_{12}O_6$ is 6:6.

   c. Six moles of CO_2 are required to produce one mole of $C_6H_{12}O_6$. Therefore, if one mole of CO_2 occupied 2 liters it would require 12 liters of CO_2 to produce one mole of $C_6H_{12}O_6$.

Name ______________________________

MODULE C2 - 7 EXAMINATION

1. What is meant by the atomic weight of a substance?

2. How many moles are there in the following: (You may use the Periodic Table)

   a. 50 grams of H_2O

   b. 340 grams of NaOH

   c. 38 grams of H_2SO_4

   d. 3 grams of H_2O_2

3. What are the molecular weights of the following:

   a. $CaCO_3$

   b. N_2H_4

   c. O_3

   d. NH_4NO_3

4. What is meant by the molecular formula of a compound?

5. Balance the following equation:

$$C_6H_6 + O_2 \text{ ----- } CO_2 + H_2O$$

MODULE C2 - 7 EXAMINATION SOLUTION SET

1. Atomic weight is the mass of an atom expressed in atomic mass units.

2. a. 1 mole of H_2O = 18g
   Therefore, 50g H_2O = 50g/18g moles = 2.7 moles

   b. 1 mole of NaOH = 40g
   Therefore, 340g NaOH = 340g/40g moles = 8.5 moles

   c. 1 mole of H_2SO_4 = 98g
   Therefore, 38g of H_2SO_4 = 38g/98g moles = .38 moles

   d. 1 mole of H_2O_2 = 34g
   Therefore, 3g H_2O_2 = 3g/34g moles = .09 moles

3. a. $CaCO_3$ = 100 amu
   b. N_2H_4 = 32 amu
   c. O_3 = 48 amu
   d. NH_4NO_3 = 80 amu

4. Molecular formula is the forumla representing a given compound. This formula indicates the composition of atoms required to form one molecule of the compound. For example, H_2O is a molecular formula. It indicates that two atoms of hydrogen and one atom of oxygen are required to form one molecule of H_2O.

5. $2C_6H_6 + 15O_2 \longrightarrow 12CO_2 + 6H_2O$

Name ______________________

MODULE C2 - 8 EXAMINATION

1. How many moles of C are there in each of the following:

   a. $C_6H_{12}O_6$

   b. CO_2

   c. C_6H_6

   d. C_4H_{10}

2. What is meant by gram molecular weight?

3. Balance the following equations:

   a. $SO_2 + O_2 \longrightarrow SO_3$

   b. $CS_2 + Cl_2 \longrightarrow CCl_4 + S_2Cl_2$

4. How many moles are there in 3840 grams of $C_6H_{12}O_6$?

5. What is the mass of 350 liters of NH_3?

6. Define atomic weight.

MODULE C2 - 8 EXAMINATION SOLUTION SET

1. a. 6 moles
   b. 1 mole
   c. 6 moles
   d. 4 moles

2. The gram molecular weight of a substance is the molecular weight expressed in grams. It means that 6.02 x 10^{23} molecules of the compound indicated by the molecular formula are contained in the gram molecular weight.

3. a. $2SO_2 + O_2 \longrightarrow 2SO_3$

   b. $CS_2 + 3Cl_2 \longrightarrow CCl_4 + S_2Cl_2$

4. 1 mole of $C_6H_{12}O_6$ = 180g
   Therefore, 3840g of $C_6H_{12}O_6$ = 3840g/180g moles = 21.3 moles

5. 1 mole of NH_3 = 17g   1 mole of NH_3 = 22.4 liters
   350 liters of NH_3 = 350l/22.4l moles = 16 moles
   16 moles of NH_3 = 17g x 16 = 272g

6. Atomic weight is the mass of an atom expressed in atomic mass units.

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Name ________________________

MODULE C2 - 9 EXAMINATION

1. Balance the following equations:

   a. $Na_3N + H_2O \longrightarrow NaOH + NH_3$

   b. $Na_2C_2 + H_2O \longrightarrow NaOH + C_2H_2$

   c. $Na + H_2O \longrightarrow NaOH + H_2$

2. How many moles are there in 2850 grams of $C_6H_{12}O_6$?

3. What is Avogadro's number and how can it be used in chemistry?

4. How many grams are there in 7/8 mole of each of the following:

   a. O_2

   b. CO_2

   c. HCO_3

   d. CH_4

5. What does it mean to oxidize a compound?

MODULE C2 - 9 EXAMINATION SOLUTION SET

1. a. $Na_3N + 3H_2O \longrightarrow 3NaOH + NH_3$

   b. $Na_2C_2 + 2H_2O \longrightarrow 2NaOH + C_2H_2$

   c. $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

2. 1 mole of $C_6H_{12}O_6$ = 180g
   Therefore, 2850g of $C_6H_{12}O_6$ = 2850g/180g moles = 16 moles

3. Avogadro's number is 6.02×10^{23} particles. It indicates the number of particles in one gram molecular weight of an element or a compound. One gram mole of every substance contains 6.02×10^{23} particles.

4. a. One mole of oxygen = 16g
   Therefore 7/8 mole = 7/8 x 16 = 14g

   b. One mole of CO_2 = 44g
   Therefore 7/8 mole = 7/8 x 44g = 38.5g

   c. One mole of HCO_3 = 61g
   Therefore, 7/8 mole = 7/8 x 61 = 53.4g

   d. One mole of CH_4 = 20g
   Therefore 7/8 mole = 7/8 x 20g = 17.5g

5. Oxidation is a reaction in which there is a loss of electrons or an increase in oxidation number of an element to a more positive number.

Name ______________________

MODULE C2 - 10 EXAMINATION

1. How many moles are there in each of the following:

   a. 68 liters CO.

   b. 627 grams H_2SO_4

   c. 500 liters O_3

2. What is Avogadro's number and how is it used in chemistry?

3. How many moles are there is each of the following:

   a. 5.28×10^{19} atoms of C

   b. 3.4×10^{23} atoms of S

   c. 6.02×10^{22} atoms of He

4. How many grams are there in each of the masses listed in question 3?

   a.

   b.

   c.

MODULE C2 - 10 EXAMINATION SOLUTION SET

1. a. 1 mole of CO = 22.4 liters
   Therefore, 68 liters = 68l/22.4l moles = 6 moles

   b. 1 mole of H_2SO_4 = 98 g
   Therefore, 627g = 627g/98g moles = 6.4 moles

   c. 1 mole of O_3 = 22.4 liters
   Therefore 500 liters = 500l/22.4l moles = 22.3 moles

2. Avogadro's number is 6.02×10^{23} particles. It indicates the number of particles in one gram molecular weight of an element or a compound. One gram mole of every substance contains 6.02×10^{23} particles.

3. One mole of any element = 6.02×10^{23} atoms.

   a. $\frac{5.28 \times 10^{19}}{6.02 \times 10^{23}} = \frac{5.28 \times 10^{-4}}{6.02} = .87 \times 10^{-4}$ moles of C

   b. $\frac{3.4 \times 10^{23}}{6.02 \times 10^{23}} = \frac{3.4}{6.02} = .56$ moles of S

   c. $\frac{6.02 \times 10^{22}}{6.02 \times 10^{23}} = 1 \times 10^{-1} = .1$ moles of He

4. a. One mole of C = 12g
   Therefore, $.87 \times 10^{-4}$ moles = $.87 \times 10^{-4} \times 12g = .001044g$

   b. One mole of S = 32g
   Therefore, .56 moles = $.56 \times 32g = 17.92g$

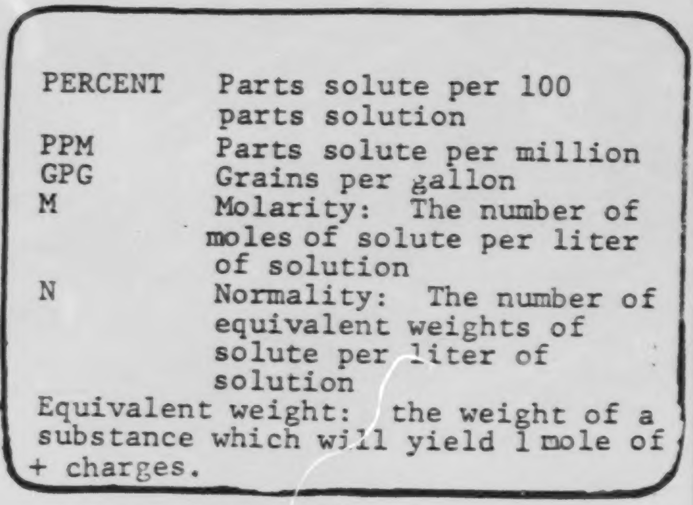
   c. One mole of He = 4g
   Therefore, .1 moles = $.1 \times 4g = .4g$

MODULE C-3 SOLUTIONS

Module C-3, Solutions, is the third of four C level modules. In this module, the student studies the following concepts: percent concentration; parts per million (ppm); molarity; equivalent weights; normality; normal-molar conversions; dilution; solubility; nature of materials; temperature, pressure and neutralization; and hydrogen ion concentration (pH). As a result of this study, the student will be able to define and discuss the inclusive concepts, and make the calculations involved with the various concepts.

In this unit we will consider some ways of measuring concentrations of solutions, some factors affecting solubility, and acid-base reactions in solutions.

Advance your slide carrousel to slide number one. Here you will find listed some ways of defining the concentration of solution. Percent by weight or volume is commonly used. The antifreeze solution in an auto-



PERCENT	Parts solute per 100 parts solution
PPM	Parts solute per million
GPG	Grains per gallon
M	Molarity: The number of moles of solute per liter of solution
N	Normality: The number of equivalent weights of solute per liter of solution

Equivalent weight: the weight of a substance which will yield 1 mole of + charges.

SLIDE #1

mobile radiator is usually about 50% ethylene glycol ($C_2H_4OH_2$). That is, about ½ of the total volume of the solution is antifreeze.

Parts per million and parts per billion on a basis of either weight or volume are used for dilute solutions such as boiler water. The concentration of impurities in boiler water are usually measured in parts per million (ppm).

Grains per gallon is also sometimes used to measure low concentrations. A grain is about 1/7000 lb. One grain per gallon is 17.118 parts/million. You don't need to memorize the 17.118, or 1/7000 but you should be aware that a grain is quite small.

Molarity is the number of moles per liter of solution. Normality is the number of equivalents per liter of solution. Both of these are quite important to a chemist. We will consider them separately.

Look at slide number two. Molarity can be calculated by converting the weight of solute in a liter of solution to moles. If you

See Page 175A - Following

SLIDE #2

MOLARITY: THE NUMBER of MOLS of SOLUTE
PER LITER of SOLUTION

GIVEN: 24.5 GRAMS H_2SO_4
1 L SOLUTION

FIND: MOLARITY

① MOL WT H_2SO_4: 2 H @ 1 EACH 2
1 S @ 32 EACH 32
4 O @ 16 EACH 64
98

② NUMBER MOLS, N = WEIGHT/MOL WT

$$\frac{24.5 \text{ GRAMS}}{98 \text{ GRAMS/MOLS}} = .25$$

THEREFORE: .25 MOLAR OR .25 M

SLIDE #2

will recall, this is done by dividing the given weight by the molecular weight.

Suppose you have 24.5 grams of sulfuric acid (H_2SO_4) diluted to a liter. What is the molarity of the solution? First, find the number of moles in 24.5 grams. The molecular weight of sulfuric acid (H_2SO_4) is 98. The number of moles (n) equals the actual weight, 24.5 grams divided by the molecular weight, 98 grams. The ratio equals .25. Therefore, the solution is .25 molar. Notice that the basis was 1 liter of solution. If another volume were the basis, the results would have to be shifted proportionately.

Look at slide number three. ¼ mole in ½ liter is the same as ½ mole per liter. On the other hand, ½ liter of ¼ molar solution contains 1/8 mole.

See Page 176A - Following

SLIDE #3

Try this one. What is the molarity of 1 liter of solution which contains 47.0 grams of magnesium chloride ($MgCl_2$)? The formula for magnesium chloride is $MgCl_2$. You

① GIVEN: 1/4 MOL IN 1/2 ℓ
FIND: MOLARITY, M
1/2 ℓ MUST BE DOUBLED TO GET 1 ℓ
THEREFORE, ∴ : 1/4 MOL DOUBLED
∴ SOLUTION IS 1/2 M

② GIVEN: 1/2 ℓ OF 1/4 M SOLUTION
FIND: THE QUANTITY OF SOLUTE
1/2 ℓ (1/4 MOLS/ℓ) = 1/8 MOLS

OR GENERALLY: VOLUME X MOLARITY = # MOLS

$$VM = n$$

SLIDE #3

may want to look at slide number two as you are doing this problem.

Advance to slide number four. Your answer should compare with that given on the slide. If you are having trouble, go back and review the definition of molarity. Once you have this definition clearly in mind, these problems are usually easy to do.

MOL WT. M_6CL_2

1 M_6 @ 24 = 24
2 CL @ 35 = 70/94

# of moles = N = weight/mol. wt
= 47 grams/94grams/mole
= 0.5 moles

Since the basis was 1 liter - no adjustment is required -

Therefore, concentration = 0.5M

SLIDE #4

Look at slide number five. Normality is somewhat more difficult a concept. Normality is defined as the number of equivalents per liter. An equivalent weight is the weight of a substance that produces 1 mole of positive charges when dissolved. For example, when hydrochloric acid (HCl) ionizes, each mole of hydrochloric acid (HCl) produces 1 mole of positive changes, that is, one mole of hydrogen (H^+) ions. By comparison, 1 mole of sulfuric acid (H_2SO_4) yields 2 moles of positive ions (H^+ in this case). Therefore, only ½ mole of sulfuric acid (H_2SO_4) is needed to produce the same number of positive charges as 1 mole of hydrochloric acid (HCl).

NORMALITY - The # of equivalents/liter

EQUIVALENT - The quantity of material that produces 1 mole of positive charges in solution

1 mole HCL -- 1 mole H^+ + 1 mol Cl^-
equivalent wt =mole wt

½ mole H_2SO_4 -- 1 mole H^+ + $SO_4^=$
equivalent wt = ½ mol wt

SLIDE #5

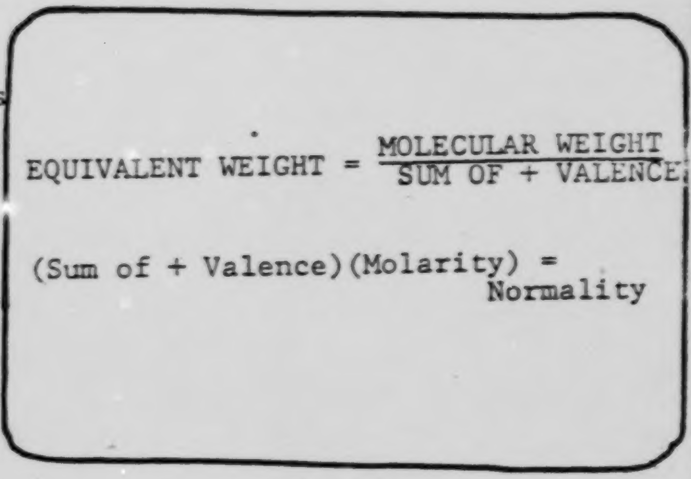
We can say that the equivalent weight of the sulfuric acid (H_2SO_4) is ½ the molecular weight.

Advance your carrousel to slide number six. Operationally, that is, in practice, equivalent weight equals the molecular weight divided by the sum of the positive valence. The relationship between molarity and normality is a factor equal to the sum of the positive valence as you can see in the second equation on slide number six.

Look at slide number seven. Calcium phosphate, $Ca_3(PO_4)_2$, ionizes to form 6 positive charges per mole. Therefore, only 1/6 mole $Ca_3(PO_4)_2$ is required to produce 1 mole of positive charges. The normality is 6 times the molarity.

Look at slide number eight. Calculate the equivalent weights of the molecules listed here.

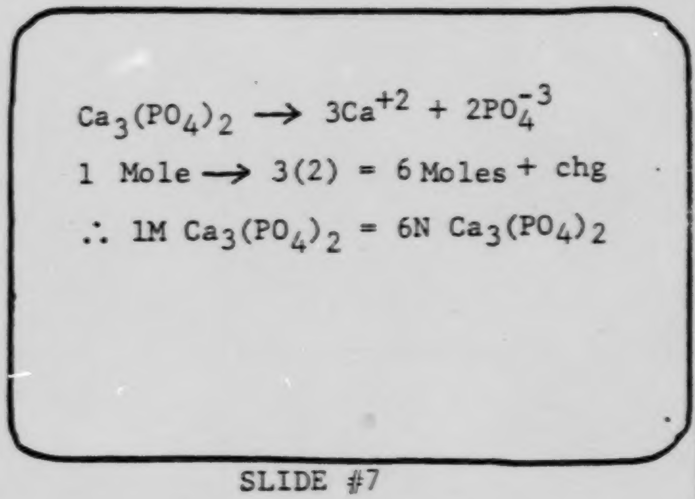
Look at slide number nine. The answers you obtained should be the same as those listed here. If they are not, return to slide number five and look at the calculations



$$\text{EQUIVALENT WEIGHT} = \frac{\text{MOLECULAR WEIGHT}}{\text{SUM OF + VALENCE}}$$

(Sum of + Valence)(Molarity) = Normality

SLIDE #6

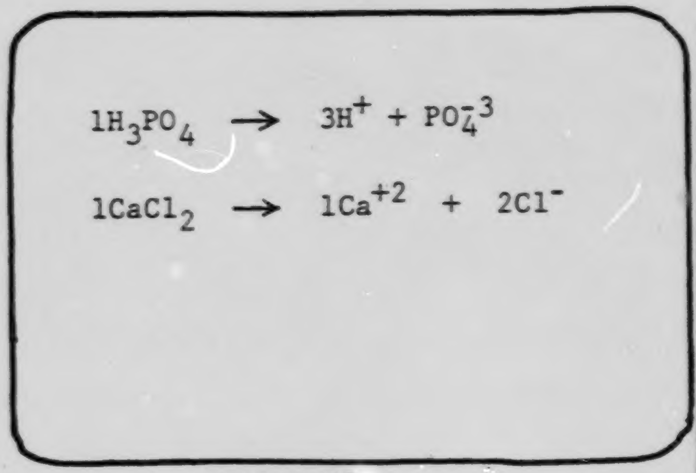


$$Ca_3(PO_4)_2 \rightarrow 3Ca^{+2} + 2PO_4^{-3}$$

$$1\text{ Mole} \rightarrow 3(2) = 6\text{ Moles + chg}$$

$$\therefore 1M\ Ca_3(PO_4)_2 = 6N\ Ca_3(PO_4)_2$$

SLIDE #7



$$1H_3PO_4 \rightarrow 3H^+ + PO_4^{-3}$$

$$1CaCl_2 \rightarrow 1Ca^{+2} + 2Cl^-$$

SLIDE #8

again.

Suppose you had 55 grams of calcium chloride and dissolved it in 1 liter. What would the normality and molarity of the solution be? Refer to slide number nine.

Now advance to slide number ten. The problem is worked out for you there. If you didn't get the answer, work the problem through step by step referring to the slide when necessary. If it makes no sense after you have learned the terminology and given the problem solving a real try, see your instructor.

Look at slide number eleven. The number of equivalents in any amount of solution can be calculated by multiplying the volume by the normality. Notice that liters cancel.

This principle can be used in problems involving dilution. If an amount of solution is diluted, the amount of solute remains constant while the amount of solvent is increased. The number of equivalents, and therefore, V times N, is a constant. If the volume is doubled, the strength,

See Page 179A - Following

SLIDE #9

# Moles $CaCl_2$ = wt/mol wt
= 55g/110g/mole
= ½ moles

½ mol/1 = ½ molar or ½ M

Sum of + val = 2
N = (Σ + val)(M)
= 2(½) = 1

The solution is 1 normal

SLIDE #10

Volume (Normality) = # of equivalents

$\cancel{\text{liters}}\left(\frac{\text{equivalents}}{\cancel{\text{liter}}}\right)$ = equivalents

V N = # of equivalents

SLIDE #11

$$1H_3PO_4 \rightarrow 3H^{+1} + PO_4^{-3}$$

$$\text{SUM} + \text{VAL} = (3(+1) = 3$$

$$\text{EQUIV WT.} = \frac{\text{MOL. WT}}{+\text{VAL}}$$

$$= \frac{98 \text{ g/MOL.}}{3}$$

$$= 32\,{}^{2}/_{3} \text{ GRAMS}$$

$$1CaCl_2 \rightarrow 1Ca^{+2} + 2Cl^{-}$$

$$\Sigma + \text{VAL.} = 1(2) = 2$$

$$\text{EQUIV. WT.} = \frac{110}{2} \text{ g/MOL} = 55 \text{ GRAMS}$$

SLIDE #9

that is, the normality is cut in half and so on.

Look at slide number twelve. Suppose that 500 milliliters of a .66 normal solution is diluted to 1500 mil. What is the normality of the diluted solution?

See Page 180A - Following

SLIDE #12

Before dilution, the solution will have some amount of solute, K, which is calculated by multiplying volume times normality. This amount of solute remains constant. Therefore, the diluted volume times normality product must be the same as the undiluted volume times normality product and so the products must be equal to each other. Substituting in numbers then gives us a diluted normality of .22.

Let us consider a realistic case. You are out at sea. A routine boiler water check shows a reddish color. After pondering this development, you wonder if the boiler water hasn't turned acid and the inside of the boiler is dissolving. You take the sample to your new Bull and Roberts water testing cabinet to test for

UNDILUTED: $V_U N_U = K =$ SOME AMOUNT OF SOLUTE

DILUTED: $V_D \quad N_D = K =$ SAME AMOUNT OF SOLUTE AS UNDILUTED

$$\therefore V_U N_U = K = V_D N_D$$

or... $V_U N_U = V_D N_D$

$$500\text{ml}(.66\text{N}) = 1500\text{ml}(N_D)$$

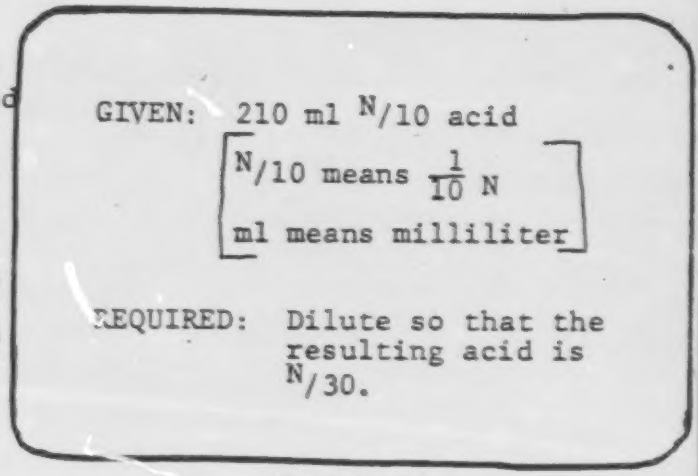
$$ND = \frac{500(.66)}{1500}$$

$$= .22$$

SLIDE #12

total alkalinity. As you open the cabinet, a bottle which wasn't secured rolls out and smashes on the floor. You quickly look down to see what it was. The label says N/30 acid. Being in a hurry, you kick the glass aside and reach for the manual. After fumbling through the manual awhile, you find the total alkalinity test and begin to read. The first thing that is needed is N/30 acid. Yes, the bottle which was just smashed was the one you need.

The old Drew cabinet hasn't been thrown away yet (you didn't get around to it). Most of the stuff in the cabinet is broken or missing, but a bottle containing some N/10 acid is still there.



GIVEN: 210 ml $^{N}/10$ acid

[$^{N}/10$ means $\frac{1}{10}$ N

ml means milliliter]

REQUIRED: Dilute so that the resulting acid is $^{N}/30$.

SLIDE #13

Advance to slide number thirteen. N/10 acid is not N/30 acid but it can be converted. You pour the N/10 acid from the old Drew cabinet into a graduated cylinder. It measures 210 ml. The question now is, how much water must you add so that the acid can be used in the Bull and Roberts total alkalinity test? See if you can figure it out.

Look at slide number fourteen. The last step is so simple that many people forget it, but it is important nonetheless.

See Page 182A - Following

SLIDE #14

Look at slide number fifteen. As a result of studying this section, you should be able to recognize the definitions of ppm, gpg, equivalent weight, molarity, and normality. In addition, you should be able to calculate equivalent weight, molarity, normality and do dilution problems.

BE ABLE TO IDENTIFY DEFINITIONS OF:

- PERCENT - %
- PPM
- GPG

IDENTIFY DEFINITIONS AND CALCULATE:

- MOLARITY
- NORMALITY
- EQUIVALENT WEIGHT

BEAABLE TO DO DILUTION PROBLEMS --

SLIDE #15

In the second section we will briefly consider factors which affect solubility.

Advance your carrousel to slide number sixteen. The factors we will consider are (1) nature of the solute and solvent, (2) temperature, and (3) pressure. Let us consider them one by one.

FACTORS AFFECTING SOLUBILITY:

- Nature of the solute and solvent -- comparability of their internal bonding
- Temperature
- Pressure - gases only

SLIDE #16

Normally, polar solvents, such as water, will dissolve ionic or ionizable materials and materials which are similar to ionizable materials. Water dissolves most salts which ionize, and will dissolve some organic

GIVEN: 210 Ml N/10 ACID SOLUTION

QUESTION : HOW MUCH WATER TO ADD TO MAKE
N/30 ACID

① THE AMOUNT OF ACID IN SOLUTION REMAINS CONSTANT — ONLY WATER IS ADDED

② THEREFORE:

$$V_U N_U = V_D N_D$$

$$V_D = \frac{V_U N_U}{N_D} = \frac{210\,{}^1\!/_{10}}{{}^1\!/_{30}}$$

$$V_D = 630 \text{ Ml FINAL VOLUME}$$

③ ORIGINAL VOLUME WAS 210 Ml

THEREFORE ADD: 630 - 210

OR 420 Ml

SLIDE #14

substances such as alcohol which has some similarity in structure. It will not dissolve materials which will not ionize or which are dissimilar.

Look at slide number seventeen. In the case of alcohols, the solubility decreases as the carbon chains become longer. Methyl alcohol (CH_3OH) is not that different from HOH but amyl alcohol ($C_5H_{10}OH$) molecules are different enough to make the pentyl alcohols (5 carbon) insoluble.

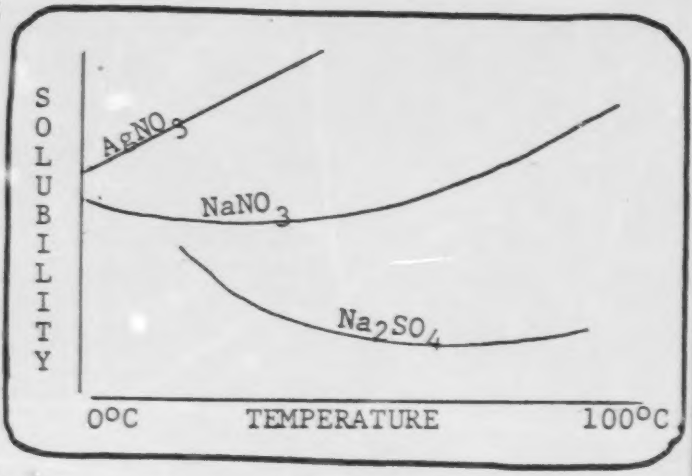
See Page 183A - Following

SLIDE #17

If, however, the material will ionize, much longer hydrocarbon chains will dissolve. Soap which is derived from stearic acid ($CH_3(CH_2)_{16}COOH$) dissolves though stearic acid is insoluble. Replacing the last hydrogen with a sodium atom which readily loses its valence electron makes the soap soluble.

Generally, it can be stated that substances with similar bonding tend to dissolve in each other.

Look at slide number eighteen. Not all salts ionize with equal ease. Furthermore, temperature greatly affects solubility. Some substances



SLIDE #18

① H_2O or $H(OH)$

DECREASING SIMILARITY
DECREASING SOLUBILITY
↓

$\underline{CH}_3(OH)$ METHANOL
$\underline{CH_3-CH_2}(OH)$ ETHANOL
$\underline{CH_3-CH_2}-CH_2(OH)$ PROPANOL

② $C_{17}H_{35}COOH \rightarrow$ NOT SOLUABLE —
STEARIC ACID
DOES NOT IONIZE AND IS STRUCTURALLY DIFFERENT FROM WATER —

$C_{17}H_{35}COONa \longrightarrow C_{17}H_{35}COO^{-} + Na^{+}$
SOAP
SODIUM STEARATE
IONIZES - THEREFORE SOLUABLE

SLIDE #17

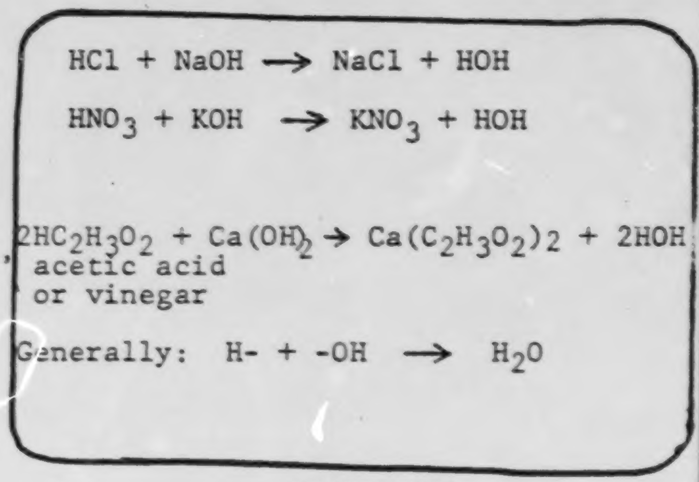
such as sodium nitrate greatly increase their solubility with temperature. A few such as sodium sulfate have decreasing solubilities as temperature increases.

The solubility curves on slide number eighteen are determined experimentally. The solubility depends on both temperature and nature of the solute.

Pressure has little affect on the solubility of solids and liquids but greatly affects the solubility of gases. The relationship is simple, as pressure on a gas increases, its solubility increases.

As a result of studying this section you should be able to name the factors which affect solubility and describe how it is affected.

Advance your carrousel to slide number nineteen. Acid base reactions, in an elementary sense, involve the formation of water. The reaction of hydrochloric acid (HCl) and sodium hydroxide (NaOH) yields a salt and water (H_2O). Acetic acid (CH_3COOH), vinegar, and calcium hydroxide



$HCl + NaOH \rightarrow NaCl + HOH$

$HNO_3 + KOH \rightarrow KNO_3 + HOH$

$2HC_2H_3O_2 + Ca(OH)_2 \rightarrow Ca(C_2H_3O_2)_2 + 2HOH$
acetic acid
or vinegar

Generally: $H- + -OH \rightarrow H_2O$

SLIDE #19

($Ca(OH)_2$), lime, yield calcium acetate and water (H_2O).

For every equivalent of acid (H^+) an equivalent of base (OH^-) is required to form 1 mole of water (H_2O). The number of equivalents of acid equals the number of equivalents of base.

You will recall that the number of equivalents of a solution equals volume times normality, or VN.

Look at slide number twenty. Since the number of equivalents of acid and base is the same, we can write the equation $V_{acid} N_{acid} = V_{base} N_{base}$. We will use this equation in the following experiment. In this experiment, we will take a sample of unknown base and titrate it against a standard acid of known concentration.

EQUIVALENTS OF ACID = EQUIVALENTS OF BASE

$$V_a N_a = V_b N_b$$

SLIDE #20

Now advance your carrousel to slide number twenty-one. It shows the equipment and materials you will need. You have done titrations before so that a detailed procedure need not be given. If you do not recall the procedure, refer back to the work you

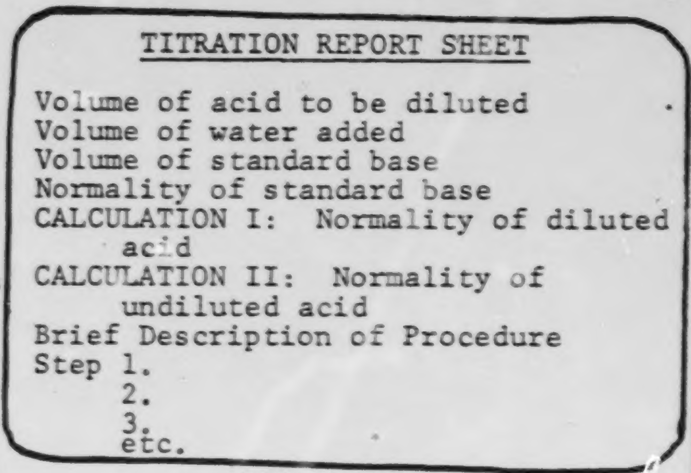
Slide shows equipment consisting of
- burettes on stand
- C3 stock acid - approx. .25N
- C3 standard base - .10N
- ehrlenmeyer flask
- graduated cylinder
- phenolphthalein solution

SLIDE #21

did earlier on in the course. Only the problem will be outlined. If you have done acid base titrations and feel that you understand them, skip this exercise. You could listen through it or skip ahead.

Take 20 ml of the unknown base solution and put it in a ehrlenmeyer flask. Add 2 drops of phenolphthalein solution for an indicator. Titrate the solution against the standard acid, adding the acid slowly from the burette until the first permanent pink color shows. Record the volumes. Calculate the strength of the unknown base.

Look at slide number twenty-two. Make up a sheet which looks like this slide.



TITRATION REPORT SHEET

Volume of acid to be diluted
Volume of water added
Volume of standard base
Normality of standard base
CALCULATION I: Normality of diluted acid
CALCULATION II: Normality of undiluted acid
Brief Description of Procedure
Step 1.
2.
3.
etc.

SLIDE #22

You should show your calculations and include the formulas which you used. Write the procedure you used as a series of steps. When finished, submit the report sheet to your instructor.

You may need to restudy this section. After you think you know what is going on, proceed with the experiment.

Look at slide number twenty-three. The last part of this section is a discussion of the measurement of the strength of acids and bases.

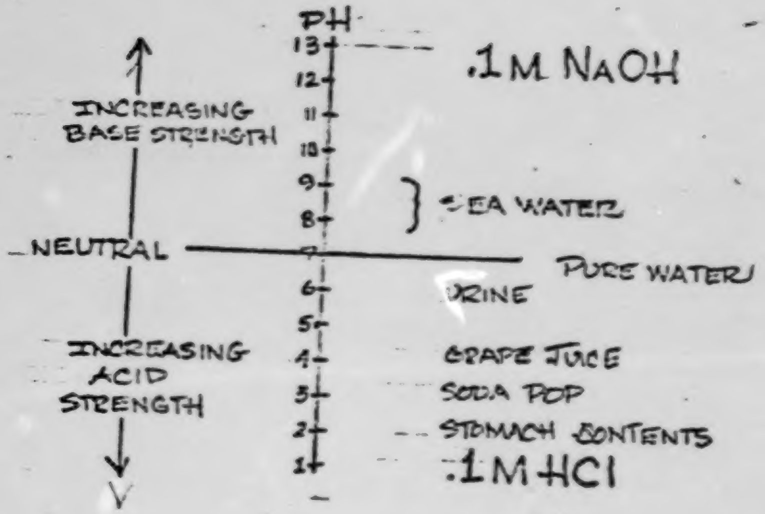
See Page 187A - Following

SLIDE #23

Hydrogen ion concentration (pH) is a way of measuring the strength of acids and bases. A pH of 7 means that the solution is neutral. Above a pH of 7 the solution becomes increasingly basic or alkaline; below a pH of 7 it becomes increasingly acid. You need not memorize the materials on the scale, they are for interest only.

Acid solutions, if you will recall, react with metals to form salts and hydrogen (H). In other words, metals seem to dissolve in acid solutions. This is why it is so important to keep the pH of boiler water above 7, but not far above.

As a result of studying this section, you should be able to calculate the strengths of solutions if you are given the titration data.


PH
13
12
11
10
9
8
7
6
5
4
3
2
1
.1 M NaOH
INCREASING BASE STRENGTH
SEA WATER
NEUTRAL
PURE WATER
URINE
INCREASING ACID STRENGTH
GRAPE JUICE
SODA POP
STOMACH CONTENTS
.1 M HCl

SLIDE #23

In addition, you should be able to discuss the effects of pH on boilers.

MODULE C-3 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed with a grade of 70% prior to taking the MODULE C-3 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE C-3 as well as to the completion of the problem set. Those pages are: 18-22, 36, 37, 41, 50-53, 61, 62, 83-94, 99, 100, 120-122, 125, 126, 129-130, 134, 200-216, 221-240, 266-268, 273, 276-278.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown. (Read Across)

Page	Problems
25	13
55	2
101	10, 11, 12
219	6
241	12
280	1, 2, 4, 7

MODULE C-3 PROBLEM SET SOLUTIONS

Page **Problem**

25 (13) a. $5/9(F - 32) = C$

$5/9(98.6 - 32) = C$

$98.6^{\circ}F = 37C$

b. $F = (9/5C) + 32$

$= (9/5 \times 1000) + 32$

$= 1832^{\circ}$

c. $C = 5/9(F-32)$

$= 5/9(0-32)$

$= -17.75^{\circ}$

d. $C = 5/9\ (-10 - 32)$

$= 5/9\ (-42)$

$= -23.3^{\circ}$

e. $F = (9/5C) + 32$

$= (9/5 \times -10) + 32$

$= 14^{\circ}$

55 (2) a. 1g O = 36.4% of the total mass

N = 63.6% of the total mass

$$\text{Mass of N/gram O} = \frac{1}{36.4} \times 63.6$$

$$= .028 \times 63.6$$

$$= 1.7752\text{g N}$$

b. 1g O = 69.6% of the total mass

N = 30.4% of the total mass

$$\text{Mass of N/gram O} = \frac{1}{69.6} \times 30.4$$

$$= .014 \times 30.4$$

$$= .4254\text{g N}$$

c. Approximately 1:4 (4254/17752)

101 (10) 88ATM + 25ATM + 50ATM = 163ATM

Problem Set
SOLUTIONS

Page **Problem**

101 (11)

$Pv = nRT$
R = Ideal gas constant = .0821
n = number of moles of gas

$$
\begin{aligned}
{}^{o}K &= {}^{o}C = 273 \\
&= 900 + 273 \\
&= 1173^{o}K
\end{aligned}
$$

$$15\ 1 \times 50\ ATM = .0821n \times 1173^{o}K$$

$$n = \frac{15 \times 50}{.0821 \times 1173}$$

= approximately 7.88 moles

1 mole Ne = 20.183g
grams Ne = 20.183 x 7.88
= 157 grams

101 (12)

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{.97 \times 1.32}{292} = \frac{1 \times V_2}{273}$$

$$\frac{273 \times .97 \times 1.32}{292} = V_2$$

$$V_2 = 1.19\ 1$$

$$M = \frac{22.4\ 1\ (STP)}{1.00\ mole} \times \frac{2.55g}{1.19\ 1\ (STP)}$$

$= \dfrac{22.4 \times 2.55g}{1.19}$ = the molecular mass of the gas
= approximately 47.7g/mole = the molecular mass of the gas

219 (6)

a. 3.00 moles
b. 1.00 moles
c. 3.00 moles
d. 3.33 moles

Page	Problem	
241	(12)	a. $Ag^+ + Cl^- \longrightarrow AgCl$ b. $Ba^{2+} + SO_4^{2-} \longrightarrow BaSo_4$ c. $HCO_3^- + OH^- \longrightarrow CO_2^{2-} + H_2O$ d. $HPO_4^{2-} + OH^- \longrightarrow PO_4^{3-} + H_2O$
280	(1)	The wood chips burn more rapidly than does the block of wood because more air is able to get to the materials being oxidized. Blowing on the chips has the same effect.
280	(2)	An increase in temperature causes the molecules to move faster. The faster they move, the more likely they are to collide with other species in the reaction, thus the rate of reaction is increased.
280	(4)	The reaction with an equilibrium constant of 10^4 goes almost to completion in a forward direction while that with an equilibrium constant of 10^{-4} goes almost to completion in a negative direction.
280	(7)	The concentration in moles per liter means the concentration in moles per unit volume. The density means the number of grams per milliliter and the densities are constant. Therefore, it follows that the concentration of a pure solid or a liquid is constant.

Name ______________________

MODULE C3 - 1 EXAMINATION

1. Define a molar solution.

2. Define an EQUIVALENT WEIGHT of a substance.

3. Define a NORMAL solution.

4. How many equivalents of a substance do I need to make 4 liters of solution at 3 normal?

5. If I add another liter of water to the above solution, what will the normality be?

6. NaOH (40 amu) is a solid (powder or pellets). How many grams of it do I need to make three liters of a 5 M solution?

7. $Ba(OH)_2$ (171 amu) is used to neutralize 30 ml of H_2SO_4 (98 amu). If the acid is 3M, how many grams of $Ba(OH)_2$ will be needed?

MODULE C3 - 1 EXAMINATION SOLUTION SET

1. A molar solution is a solution expressed in terms of concentration of solute per liter of solution. A one molar solution contains 1 mole of solute per liter of solution.

2. An equivalent weight or a gram equivalent is the molecular weight divided by sum of the positive valence. The gram equivalent of an oxidizing agent is mass of the substance which picks up the Avogadro number of electrons. The gram equivalent of a reducing agent is the mass of the substance that reduces the Avogadro number of electrons. Liters of solution x normality of solution = gram equivalents of solute in the sample.

3. Normality indicates the number of gram equivalents necessary to neutralize a substance. For example, one mole of H_2SO_4 in solution produces a one molar solution but contains two moles of H^+ charges. Therefore, it is a 2 normal solution and 2 moles of OH^- are necessary to neutralize the solution.

4. Liters of solution x normality = gram equivalents.
   4 liters x 3 normal = 12 equivalents

5. $\text{normality} = \frac{\text{equivalents}}{\text{liters}}$ $\qquad$ $N = 12/5 = 2.4N$

6. 1 mole of NaOH = 40g and a 1 molar solution contains 1 mole of solute per liter of solution.

   A 5 molar solution then requires 5 moles of solute/liter.

   Therefore, 3 liters of 5 molar NaOH requires 15 moles of NaOH or 15 x 40g NaOH = 600g.

7. A 3 molar solution contains 3 moles of H_2SO_4 per liter or 294g H_2SO_4/liter. 30 ml is 30/1000 liter or 3/1000 which means 3/100 x 3 moles H_2SO_4 are contained herein. H_2SO_4 produces 2 gram equivalents H^+ per mole. Therefore, 2 gram equivalents of OH^- are required per mole to neturalize the solution. $Ba(OH)_2$ produces 2 gram equivalents/mole of OH^-.

   One mole of $Ba(OH)_2$ = 171g
   3 moles of $Ba(OH)_2$ = 513g and 3/100 x 513g of $Ba(OH)_2$ are required to neutralize the solution or 15.39g.

Name ______________________________

MODULE C3 - 2 EXAMINATION

1. I have 500 ml of H_2SO_4 at a concentration of 3M. How many grams of NaOH (40 amu) do I need to neutralize it?

2. What do we mean by the "EQUIVALENT WEIGHT" of a substance?

3. I have some DREW sulphuric acid at N/10. I wish to use it for the Bull and Roberts tests which call for N/30 acid. If I have one liter of the N/10 acid, how much water do I add to dilute it to the N/30 concentration?

MODULE C3 - 2 EXAMINATION SOLUTION SET

1. Each mole of H_2SO_4 produces 2 moles of H^+ ions. Therefore, a 3 molecular solution of H_2SO_4 contains 6 moles of H^+ ions per liter of solution.

   Since there is 1/2 liter of H_2SO_4 present 3 moles of H^+ ions are present. It follows that 3 moles of OH^- ions are required for neutralization.

   NaOH produces one mole of OH^- ions per mole of NaOH; therefore, three moles of NaOH will be required for neutralization

   1 mole of NaOH = 40g
   3 moles of NaOH = 120g

2. a. 1 mole C_3H_8 = (3 x 12) + (8 x 1)
   = 48g + 8g
   = 56g

   ? moles in 358g = 358/56 = 6.4 moles

   b. 1 mole H_2SO_4 = 98g

   ? moles in 5000g = 5000/98 = 52 moles

3. A 1/10 normal solution contains 1/10 mole of H^+ ions per liter.

   A 1/30 normal solution contains 1/30 of a mole of H^+ ions per liter of solution.

   In order to dilute 1/10 normal 1 liter solution to 1/30 normal, 2 liters of H_2O must be added.

Name ______________________________

MODULE C3 - 3 EXAMINATION

1. How many grams of NaOH (40 amu) do I need to make 3 liters of a 4 molar solution?

2. How many grams of phosphoric acid, H_3PO_4, do I need to make two liters of a four normal solution?

3. If I neutralize 250 ml of H_2SO_4 with 3N NaOH and it took 150 ml of the base, how strong was the acid?

4. I need 100 ml of 2N H_2SO_4. I have some 10N H_2SO_4. How much acid and how much water do I use to make the needed solution?

MODULE C3 - 3 EXAMINATION SOLUTION SET

1. 4 moles of NaOH are needed to make 1 liter of 4 molar solution. Therefore, 12 moles are required to make 3 liters of 4 molar solution.

   1 mole of NaOH = 40g 12 moles of NaOH = 480g

2. 1 mole of H_3PO_4 dissolved in 1 liter of H_2O will produce 3 moles of H^+ ions or a 3N solution.

   1-1/3 moles of H_3PO_4 in 1 liter of H_2O will produce a 4N solution. In order to produce 2 liters of 4N solution, 2-2/3 moles of H_3PO_4 will be required.

   1 mole of H_3PO_4 = 98g
   a 4N, 2 liter solution of H_3PO_4 requires 98g x 2-2/3 = 261.3g.

3. Since NaOH produces one mole of OH^- ions per liter, a 3N, 1 liter solution would contain 3 moles of OH^- ions. 150ml of 3N NaOH would contain:

   $\frac{150\text{ml}}{1000\text{ml}}$ x 3 moles of OH^- ions or .45 moles of OH^- ions.

   It follows that the 250ml of H_2SO_4 must contain .45 moles of H^+ ions. Therefore, one liter of the H_2SO_4 solution must contain 1.8 moles of H^+ ions. This means the solution is 1.8N but since each mole of H_2SO_4 per liter contributes 2 moles of H^+ ions, the solution must be .9 molar.

4. 100 ml of 2N H_2SO_4 contains .2 moles of H^+ ions while 20ml of 10N H_2SO_4 contains .2 moles of H^+ ions. Therefore, 100ml of 2N H_2SO_4 can be made by taking 20 ml of 10N H_2SO_4 and diluting it to 100 ml.

Name ______________________

MODULE C3 - 4 EXAMINATION

1. Define the following:

    a. ppm

    b. %

    c. gpg

    d. Molarity

    e. Normality

    f. Equivalent weight

2. Convert the following to molarity:

    a. 5 N HCl = ________________M

    b. 2 N NaOH = ________________M

    c. 2 N H_2SO_4 = ________________M

    d. 3 N H_3PO_4 = ________________M

3. How many equivalent weights are in 2 liters of:

    a. 5 M HCl ________________

    b. 5 M NaOH ________________

    c. 5 M H_2SO_4 ________________

    d. 5 N H_2SO_4 ________________

4. How volume of water must be added to dilute 250 ml of 1 N H_2SO_4 to make .2 N H_2SO_4?

5. What would the final volume of acid be if you wished to dilute 300 ml of 2 M H_3PO_4 to make .25 N acid?

Continued
P. 200

6. What volume of .1 N NaOH would be required to neutralize 500 ml of .25 N H_2SO_4?

7. What is the normality of a base if 300 ml are needed to neutralize 500 ml of .5 M HCl?

MODULE C3 - 4 EXAMINATION SOLUTION SET

1. a. ppm means parts per million. It means the number of parts of one agent per million parts of another.

   b. % refers to percent solution. It usually refers to the percent of a pure agent dissolved in H_2O. For example, a 5% solution of alcohol means that for every 100ml, 95ml are H_2O and 5ml are alcohol.

   c. gpg means grains per gallon. A grain is about 1/7000 lb. and one grain per gallon is about 17.118 parts/million.

   d. the molarity is the number of moles of solute per liter of solution.

   e. an equivalent weight or gram equivalent is the molecular weight divided by sum of the positive valence. The gram equivalent of an oxidizing agent is mass of the substance which picks up the Avogadro number of electrons. The gram equivalent of a reducing agent is the mass of the substances that reduces the Avogadro number of electrons. Liters of solution x normality of solution = gram equivalents of solute in the sample.

2. a. HCl contributes one mole of H^+ ions per liter so 5N = 5M

   b. NaOH contributes one mole of OH^- ion per liter so 2N = 2M.

   c. H_2SO_4 contributes two moles of H^+ ions per liter so 2N = 1M

   d. H_3PO_4 contributes three moles of H^+ ions per liter so 3N = 1M.

3. a. 2 liters of 5M HCl contains 10 moles of HCl and each mole contributes one mole of H^+. Therefore, the equivalent weight is (1 mole HCl = 36.4) 364g.

   b. NaOH contributes one mole of OH^- ions per mole. Therefore, there would be 10 equivalent weights in 2 liters of 5M NaOH.

      1 mole of NaOH = 40g   10 equivalent weights of NaOH = 400g.

   c. H_2SO_4 contributes 2 moles of H^+ ions per liter. Therefore, one equivalent weight of H_2SO_4 = ½ mole of H_2SO_4. It follows that 2 liters of 5M H_2SO_4 contains 20 equivalent weights.

   d. 5N H_2SO_4 contains 5 equivalents per liter or 10 equivalents in two liters.

4. 1 liter of 1N H_2SO_4 contains one mole of H^+ ions. Therefore, 250ml contains ¼ mole of H^+ ions. One liter of .2N H_2SO_4 contains 1/5 mole of H^+ ions. The problem is to dilute the original 250ml of 1N H_2SO_4 until it contains 1/20 mole of H^+ ions per 250 ml. This is accomplished by adding 1 liter of H_2O to the original 250 ml of 1N H_2SO_4.

5. Each mole of H_3PO_4 contributes 3 moles of H^+ ions per liter of solution. Therefore, 1 liter of 2M H_2PO_4 contains 6 moles of H^+. .25N acid requires .25M of H^+ ions per liter of solution. The addition of 23 liters of H_2O (total volume 241) will dilute a 2M H_3PO_4 solution to .25N. It follows that 300ml of 2M H_3PO_4 must be diluted as follows:

$$\frac{300\text{ml}}{1000\text{ml}} \times 241 = 7.2 \text{ liters}$$

6. One liter of .25N H_2SO_4 contains .25 moles of H^+ ions. Therefore, 500ml of the solution contains 1/8 moles of H^+ ions. The volume of NaOH required to neutralize this solution then will have to contain 1/8 or .125 moles of OH^- ions. A .1N NaOH solution contains .1 moles of OH^- ions per liter. This means that 1.25 liters of .1N NaOH will contain .125 moles of OH^- ions. 1.25 liters of NaOH then is required to neutralize 500 ml of .25N H_2SO_4.

7. A .5M HCl solution is also .5N, and 500ml of .5N HCl contains .25 moles of H^+ ions. It follows that whatever neutralizes the solution must contain .25 moles of OH^- ions. 300ml of the base used contained .25 moles of OH^- ions. The normality of the base then is

$$\frac{.25 \text{ moles}}{3} \times 10 = .83\text{N}$$

Name ____________________

MODULE C3 - 5 EXAMINATION

1. Make the following temperature conversions:

   a. 100°C to °F

   b. 99°F to °K

   c. 92°C to °K

   d. 250°K to °C

2. Define the following terms:

   a. pH

   b. neutralization

   c. equivalent weight

   d. normality

3. The percent by mass of a carbon in a compound containing carbon and oxygen is 29.8. How much oxygen is there in a sample of the compound containing 10 grams of carbon?

4. Convert the following to molarity:

   a. 5 N H_2SO_4

   b. 5 N NaOH

5. If you neutralize 500 ml of H_2SO_4 with 2 N NaOH and it takes 300 ml, how strong is the acid?

MODULE C3 - 5 EXAMINATION SOLUTION SET

1. a. $^{\circ}F = (9/5\,^{\circ}C) + 32 = (9/5 \times 100) + 32 = 212^{\circ}$

   b. $^{\circ}K = {}^{\circ}C + 273$
   $^{\circ}C = 5/9(^{\circ}F - 32) = 5/9(99-32) = 5/9 \times 67 = 37.2^{\circ}$

   $^{\circ}K = 273^{\circ} + 37.2^{\circ} = 310.2^{\circ}$

   c. $^{\circ}K = {}^{\circ}C + 273^{\circ} = 92^{\circ} + 273^{\circ} = 365^{\circ}$

   d. $^{\circ}C = {}^{\circ}K - 273^{\circ} = 250^{\circ} - 273^{\circ} = -23^{\circ}$

2. a. pH is the negative exponent of the hydrogen ion concentration.

   b. Neutralization is the reaction of an acid with a base. The H^+ and OH^- ions unite to form H_2O while the negative ion of the acid and the positive ion of the base either remain in solution or precipitate as a solid.

   c. An equivalent weight or a gram equivalent is the molecular weight divided by sum of the positive valence. The gram equivalent of an oxidizing agent is mass of the substance which picks up the Avogadro number of electrons. The gram equivalent of a reducing agent is the mass of the substances that reduces the Avogadro number of electrons. Liters of solution times normality of solution equal gram equivalents of solute in the sample.

   d. Normality indicates the number of gram equivalents necessary to neutralize a substance. For example, one mole of H_2SO_4 in solution produces a one molar solution but contains two moles of H^+ charges. Therefore, it is a 2 normal solution and 2 moles of OH^- are necessary to neutralize the solution.

3. The percent oxygen in the compound is 100% - 29.8% = 70.2%

   1% of total mass $= \frac{10}{29.8}$ g $= .37$g

   TOTAL mass = 100 x .37g = 37g

   mass of oxygen present = 37g - 10g = 27g

4. a. H_2SO_4 donates 2 moles of H^+ ions per mole of H_2SO_4 per liter. Therefore, a 5N H_2SO_4 solution is 2.5M.

   b. NaOH donates 1 mole of OH^- ions per mole of NaOH per liter. Therefore, a 5N NaOH solution is also a 5M solution.

5. 2N NaOH contains 2 moles of OH^- ions per liter. 300ml of 2N NaOH contains

$$3/10 \times 2 \text{ moles of } OH^- \text{ ions} = 1/2 \text{ mole of } OH^- \text{ ions}$$

Therefore 500ml of H_2SO_4 must contain 1/2 mole of H^+ ions. This means that one liter of H_2SO_4 contains 1 mole of H^+ ions. The acid then is 1N or 1/2M because each mole of H_3SO_4 donates 2 moles of H^+ ions.

Name ____________________

MODULE C3 - 6 EXAMINATION

1. Define the following terms:

   a. Normality

   b. Molarity

   c. Equivalent weight

   d. Parts per million

   e. Dilution

2. How many equivalent weights are there in 3.5 ml of:

   a. 2.5 M NaOH

   b. 2.5 M HCl

   c. 2.5 N H_2SO_4

3. Describe how you would make a 5M solution of NaOH.

4. Describe how you would make a 5N solution of HCl.

5. Make the following temperature conversions:

   a. 98.6°C to °F

   b. 98.6°C to °K

   c. 212°F to °K

   d. 700°K to °C

   e. 458°K to °F

MODULE C3 - 6 EXAMINATION SOLUTION SET

1. a. Normality indicates the number of gram equivalents necessary to neutralize a substance. For example, one mole of H_2SO_4 in solution produces a one molar solution but contains two moles of H^+ charges. Therefore, it is a 2 normal solution and 2 moles of OH^- are necessary to neutralize the solution.

   b. The molarity is the number of moles of solute per liter of solution.

   c. An equivalent weight or a gram equivalent is the molecular weight divided by sum of the positive valence. The gram equivalent of an oxidizing agent is mass of the substance which picks up the Avogadro number of electrons. The gram equivalent of a reducing agent is the mass of the substances that reduces the Avogadro number of electrons. Liters of solution x normality of solution = gram equivalents of solute in the sample.

   d. This is the number of parts of something contained in each million parts of solution.

   e. Dilution means to add H_2O or some other solvent to something of known strength thereby decreasing the strength.

2. a. 2.5M NaOH contains 2.5 moles of OH^- ions per liter. In addition there are 100g of NaOH in 1 liter of 2.5M NaOH. One ml of 2.5M NaOH contains .025 moles of OH^- ions and 3.5ml contains

   3.5 x .025 moles = .0875 moles

   Since 1 mole NaOH = 40g and contributes 1 mole of OH^- ions, the number of equivalent weights will equal

   40g x .0875 = 3.5g

   b. One mole of HCl = 36g and each mole of HCl contributes 1 mole of H^+ ions the number of equivalent weights will equal

   36g x .0875 = 3.15g

   c. One mole of H_2SO_4 = 98g and each mole of H_2SO_4 contributes 2 moles of H^+ ions. Therefore, the number of equivalent weights will be

   98/2g x .0875 = 4.2875g

3. A molar solution of NaOH requires that a liter of solution contain 5 moles of NaOH.

   5 moles of NaOH = 5 x 40g = 200g

   200g of concentrated NaOH is then diluted by 800ml distilled H_2O to yield a 5M NaOH solution.

4. HCl contributes 1 mole of H^+ ions per mole and a 5N solution requires 5 moles of HCl per liter.

   1 mole HCl = 36g
   5 moles HCl = 5 x 36g = 180g

   Therefore, 180g of concentrated HCl are mixed with 820ml of distilled H_2O.

5. a. $^{\circ}F = (9/5\ ^{\circ}C) + 32 = (9/5 \times 98.6) + 32 = 209.48^{\circ}$

   b. $^{\circ}K = {}^{\circ}C + 273^{\circ} = 98.6^{\circ} + 273^{\circ} = 371.6^{\circ}$

   c. $^{\circ}C = 5/9\ (^{\circ}F - 32) = 5/9\ (212 - 32) = 100^{\circ}$

   $^{\circ}K = {}^{\circ}C + 273 = 373^{\circ}$

   d. $^{\circ}C = {}^{\circ}K - 273^{\circ} = 700 - 273 = 427^{\circ}$

   e. $^{\circ}C = {}^{\circ}K - 273 = 458 - 273^{\circ} = 185^{\circ}$

   $^{\circ}F = (9/5\ ^{\circ}C) + 32 = (9/5 \times 185) + 32 = 365^{\circ}$

Name ______________________

MODULE C3 - 7 EXAMINATION

1. How many equivalent weights of the substance are required to make the following solutions:

   a. 3 N HCl

   b. 3 M HCl

   c. 3 M NaOH

   d. 5 N H_2SO_4

2. If 2 liters is added to a 4 N solution, what is the new normality?

3. Make the following temperature conversions:

   a. 300°K to °C

   b. 675°K to °F

   c. 220°F to °C

   d. 28°C to °F

4. Define the following terms:

   a. pH

   b. N-M conversion

   c. ppm

   d. per cent concentration

   e. oxidation

MODULE C3 - 7 EXAMINATION SOLUTION SET

1. One gram equivalent of an acid or a base is the quantity required to furnish one mole of either H^+ or OH^- ions.

   a. 3 equivalent weights

   b. 3 equivalent weights

   c. 3 equivalent weights

   d. 5 equivalent weights

2. Adding 1 liter to a 4N solution dilutes it to 2N and adding the second liter dilutes the solution such that it is now 1/3 of the original normality or 1-1/3N.

3. a. $°C = °K - 273° = 300 - 273 = 7°$

   b. $°C = °K - 273 = 675 - 273 = 402°$

   $°F = (9/5\ C) + 32° = (9/5 \times 402) + 32 = 755.6°$

   c. $°C = 5/9(F-32) = 5/9(220 - 32) = 104.4°$

   d. $°F = (9/5C) + 32 = (9/5 \times 28) + 32 = 82.4°$

4. a. pH is the negative exponent of the hydrogen ion concentration.

   b. This is the computation which results in finding the molarity of a solution if you know the normality or vice versa.

   c. ppm means parts per million and means the number of parts of one substance for each million parts of another substance.

   d. Percent concentration usually refers to percent of the solution which is solute. For example, a 5% alcohol solution contains 5% by volume of alcohol

   e. To oxidize means to burn.

Name ____________________

MODULE C3 - 8 EXAMINATION

1. If a 5 M solution is diluted with 2000 ml H_2O, what is the new normality?

2. How many grams of NaOH (40amu) are needed to neutralize 500 ml of 3M H_2SO_4?

3. Discuss a way in which the rate of sustained oxidation may be increased.

4. Convert the following into molarity:

   a. 10 N H_2SO_4

   b. 7.5 N HCl

   c. 4 N H_2SO_4

   d. 2 N NaOH

5. Define the following terms:

   a. pH

   b. ppm

   c. gpg

   d. equivalent weight

MODULE C3 - 8 EXAMINATION SOLUTION SET

1. If the solution is one in which the solute contributes one mole of H^+ or OH^- ions for every mole of solute, then the normality of the original solution will be 5. If 1 liter of the original solution is diluted by 2 liters of H_2O, then the new normality will be 1/3 of the original or 1-2/3.

2. Each mole of H_2SO_4 contributes 2 moles of H^+ ions, thus a 3M solution is 6N. 500ml then contains 3 moles of H^+ ions.

   1 mole of NaOH = 40g and each mole donates 1 mole of OH^- ions, therefore, 120g NaOH are required to neutralize 500ml of 3M H_2SO_4.

3. The rate of sustained oxidation (fire) may be increased by increasing the supply of available oxygen.

4. a. 5M
   b. 7.5M
   c. 2M
   d. 2M

5. a. pH is the negative exponent of the hydrogen ion concentration.

   b. ppm means parts per million and means the number of parts of one substance for each million parts of another substance.

   c. gpg means grains per gallon. A grain is about 1/7000 lb. and one grain per gallon is about 17.118 parts/million.

   d. An equivalent weight or a gram equivalent is the molecular weight divided by sum of the positive valence. The gram equivalent of an oxidizing agent is mass of the substance which picks up the Avogadro number of electrons. The gram equivalent of a reducing agent is the mass of the substances that reduces the Avogadro number of electrons. Liters of solution times normality of solution equals gram equivalents of solute in the sample.

Name ______________________________

MODULE C3 - 9 EXAMINATION

1. What is meant by the equivalent weight of a substance?

2. In a compound containing copper and sulfur, 83.2% of the mass is copper. How much sulfur is contained in a 7.5 grain sample of the sample?

3. Make the following temperature conversions:
   a. 58°F to °C
   b. 47°C to °F
   c. 63°C to °K
   d. 54°F to °K
   e. 850°K to °C

4. Define the following terms:
   a. % concentration
   b. ppm
   c. molarity
   d. normality

5. How many grams of H_3PO_4 are required to make 3.5 liters of a 2N solution?

MODULE C3 - 9 EXAMINATION SOLUTION SET

1. An equivalent weight or a gram equivalent is the molecular weight divided by sum of the positive valence. The gram equivalent of an oxidizing agent is mass of the substance which picks up the Avogadro number of electrons. The gram equivalent of a reducing agent is the mass of the substances that reduces the Avogadro number of electrons. Liters of solution times normality of solution equals gram equivalents of solute in the sample.

2. % sulfur = 100.0 - 83.2 = 16.8%. Therefore, 16.8% of the 7.5 gram sample is sulfur or 1.26g.

3. a. $^{\circ}C = 5/9(^{\circ}F - 32) = 5/9(58 - 32) = 14.4^{\circ}$

   b. $^{\circ}F = (9/5C) + 32 = (9/5 \times 47) + 32 = 116.6^{\circ}$

   c. $^{\circ}K = ^{\circ}C + 273^{\circ} = 63 + 273 = 336^{\circ}$

   d. $^{\circ}C = 5/9(^{\circ}F - 32) = 5/9(54 - 32) = 12.2^{\circ}$

   $^{\circ}K = ^{\circ}C + 273 = 12.2 + 273 = 285.2^{\circ}$

   e. $^{\circ}C = ^{\circ}K - 273 = 850 - 273 = 577^{\circ}C$

4. a. Percent concentration usually refers to percent of the solution which is solute. For example, a 5% alcohol solution contains 5% by volume of alcohol.

   b. ppm means parts per million and means the number of parts of one substance for each million parts of another substance.

   c. The molarity is the number of moles of solute per liter of solution.

   d. Normality indicates the number of gram equivalents necessary to neutralize a substance. For example, one mole of H_2SO_4 in solution produces a one molar solution but contains two moles of H^+ charges. Therefore, it is a 2 normal solution and 2 moles of OH^- are necessary to neutralize the solution.

Name ______________________

MODULE C3 - 10 EXAMINATION

1. How many equivalents of a substance are required to make the following solutions:

   a. 4 l of 3 N solution

   b. 6 l of 1/10 N solution

   c. 3 l of 4 N solution

2. How many grams of solid NaOH (40amu) are required to make 5 l of a 3 M solution?

3. Define the following terms:

   a. ppm

   b. % concentration

   c. pH

   d. N-M conversion

4. Make the following temperature conversions:

   a. 65°F to $^{\circ}$C

   b. 38°C to $^{\circ}$F

   c. 27°C to $^{\circ}$K

   d. 278°K to $^{\circ}$F

5. How much H_2O must be added to N/10 (1 l) to dilute it to N/25?

MODULE C3 - 10 EXAMINATION SOLUTION SET

1. a. 12 equivalents

   b. 6/10 equivalents

   c. 12 equivalents

2. One liter of 3M solution requires 120g NaOH. Therefore, 5 liters will require 600g.

3. a. ppm means parts per million and means the number of parts of one substance for each million parts of another substance.

   b. Percent concentration usually refers to percent of the solution which is solute. For example, a 5% alcohol solution contains 5% by volume of alcohol.

   c. pH is the negative exponent of the hydrogen ion concentration. It also indicates how acidic or basic some ing is.

   d. This is the computation which results in finding the molarity of a solution if you know the normality or vice versa.

4. a. $^{o}C = 5/9(^{o}F - 32) = 5/9(65 - 32) = 18.3^{o}$

   b. $^{o}F = (9/5^{o}C) + 32 = (9/5 \times 38) + 32 = 68.5^{o}$

   c. $^{o}K = ^{o}C + 273 = 27 + 273 = 300^{o}$

   d. $^{o}C = ^{o}K - 273 = 278 - 273 = 5^{o}$

   $oF = (9/5C) + 32 = (9/5 \times 5) + 32 = 41^{o}$

5. One liter of 1/10N solution contains 1/10 mole of either H^+ or OH^- ions and one liter of 1/25N solution contains 1/25 mole of ions. Therefore:

$$\frac{10}{1} = \frac{25}{X}$$

$$10X = 25 \text{ liters}$$

$$X = 2.5 \text{ liters}$$

So, 1.5 liters must be added to dilute from 1/10N to 1/25N.

MODULE C-4 CORROSION

Module C-4, Corrosion, is the fourth module in the series. In this module, the concepts of corrosion will be developed. As a result of studying this module, the student will be able to identify corrosion damage and its causes; discuss methods of stopping corrosion; explain the electrochemical nature of corrosion; identify the conditions of N electrolyte required for corrosion; write the basic reactions which take place at the cathode and anode in corrosion; explain why pH is low in corrosive reactions; relate raw water, CO_3 and HCO_3 to corrosion; explain H damage, what it is, and why it is difficult to prevent; explain the role of O_2 in corrosion of Cu alloys; explain how corrosion can be minimized by proper H_2O treatment; name three types of deposits in marine steam generating plants; discuss the types of treatments which are used to form suspended solids in high pressure boiler operation; and discuss the sources of feed water contamination in relation to sludge formation.

Advance your slide carrousel to slide number one. This slide shows five common types of damage caused by corrosion. You may recall that corrosion was defined as a physical or chemical weakening of a metallic structure. These types of weakening are described for you in the text, Engineer's Manual of Marine Boiler and Feedwater Treatment by Drew Chemical Corporation on page 53. You may borrow a copy of this text from your instructor for use in the laboratory. The text is also available for purchase at the Academy Bookstore, and a copy is on reserve in the Academy Library. Obtain a copy of this text and study the descriptions of each of these types of corrosion damage. You should be able to explain each of these five types of corrosion damage. The sample tubes you looked at in Unit D-2 manifested some of these types of corrosion. Can you look at the sample tube sections and identify the types of corrosion damage?

FIVE TYPES OF CORROSION DAMAGE

- Thinning
- Pitting
- Cracking
- Exfoliation
- Embrittlement

SLIDE #1

Look at slide number two. Corrosion is, by and large, an electrochemical reaction. That is, electrons are being transferred and atoms are leaving the metallic structure and forming soluble ions. Slide number two shows how an atom of iron will break away from the metal structure, leaving behind two electrons. The iron atom is now an ion. Although no longer in the crystal lattice of the metal, the ion is still loosely attached to the surface. As an ion it will more readily enter into chemical reactions with other substances.

See Page 219A - Following

SLIDE #2

Look at slide number three. The iron will react with water as shown in slide number three. However, in the presence of heat the iron hydroxide ($Fe(OH)_2$) breaks down into iron oxide, water (H_2O) and hydrogen (H).

$$3Fe + 6H_2O \longrightarrow 3Fe(OH)_2 + 3H_2$$

SLIDE #3

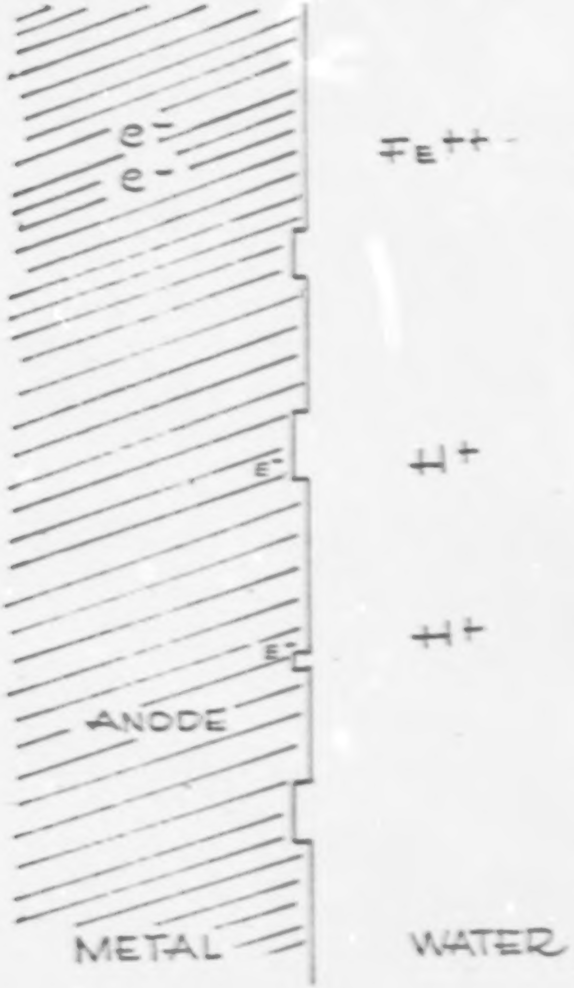
Advance to slide number four. The ferrous hydroxide ($Fe(OH)_2$) decomposes to form ferrous oxide (FeO), which is also called magnetite. Magnetite is a

$$3Fe(OH)_2 \xrightarrow{heat} Fe_3O_4 + 2H_2O + 3H_2$$

Ferrous Hydroxide

Ferrous Oxide
(Magnetite)
Protective Coating

SLIDE #4


e⁻
e⁻
FE++
H+
H+
E⁻
E⁻
ANODE
METAL
WATER

SLIDE #2

black protective coating which adheres to the iron beneath it and prevents the iron from corroding further. Many corrosion products form protective coatings. Aluminium (Al) for example, is protected by aluminium oxide. Nails are sometimes coated with zinc because the zinc (Zn) oxidizes to form zinc oxide (ZnO), another protective coating.

Look at slide number five. Here you will find an illustration of how hydrogen (H^+) ions in water (H_2O) combine with the free electrons (e^-) in the metal and form a layer of hydrogen (H) on the cathodic area of the metal. This layer of hydrogen (H) molecules also prevents further hydrogen (H^+) ions from reaching the metal surface underneath and inhibits the corrosion. If the concentration of the hydrogen (H^+) ions should become great, however, the hydrogen (H) molecules start to bubble off and the protective layer is destroyed, increasing the rate of corrosion.

See Page 220A - Following

SLIDE #5

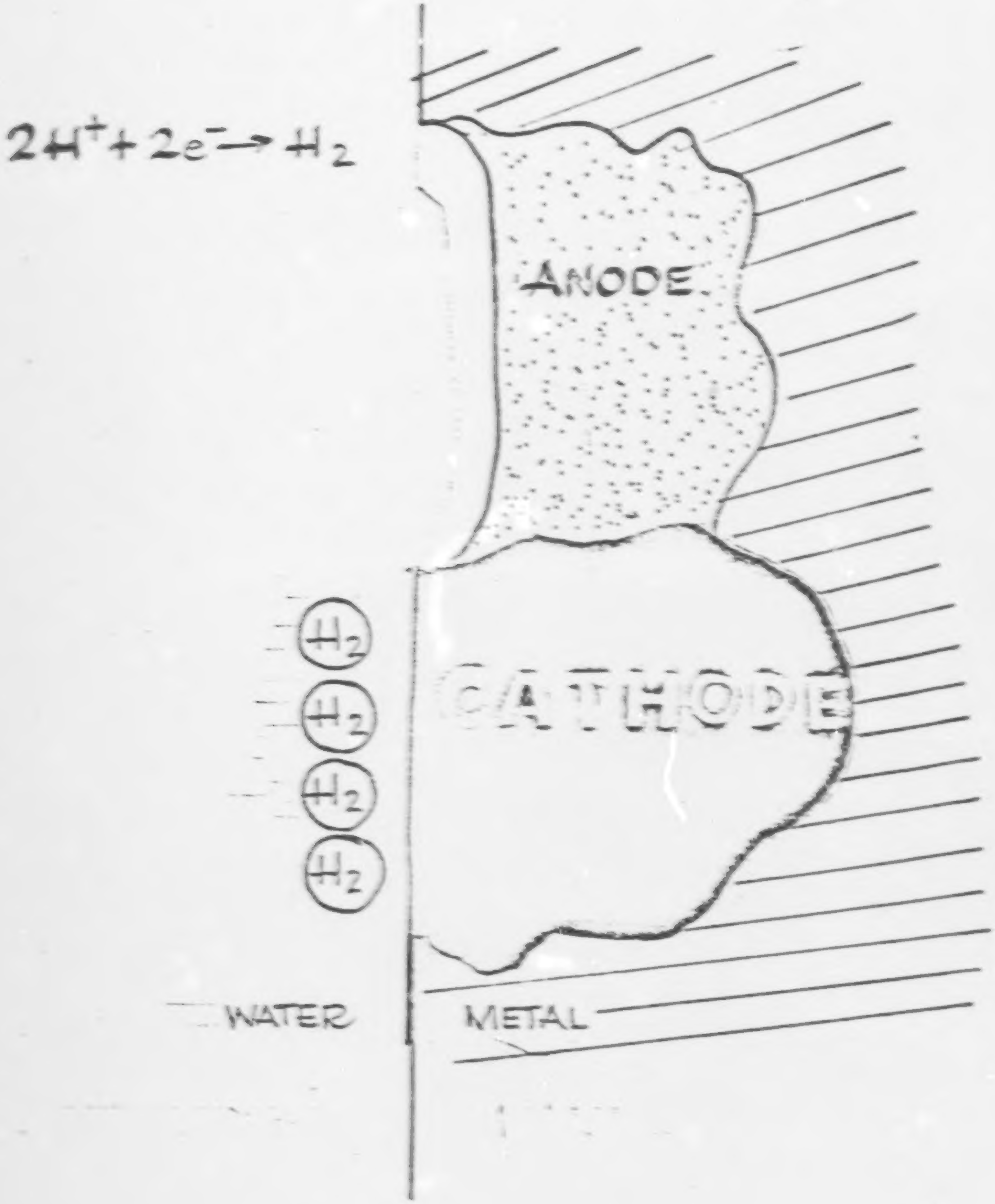
Advance to slide number six. Slide number six shows the effect of

OXYGEN REACTIONS

$Fe_3O_4 + O_2 \rightarrow Fe_2O_2$
Magnetite Rust

$H_2 + O_2 \rightarrow H_2O$
Protective Coating No Protection

SLIDE #6


$2H^+ + 2e^- \rightarrow H_2$
ANODE
CATHODE
H_2
H_2
H_2
H_2
WATER
METAL

SLIDE #5

the presence of oxygen in water. The oxygen will react with the protective magnetite to form ferric oxide (Fe_2O_3), rust. The oxygen (O) reacts with the protective hydrogen (H) layer and forms water (H_2O), exposing the surface to attack.

Look at slide number seven. There are many factors which affect the rate of corrosion. The most important are listed on slide number seven. We will go over each of them briefly here. The text, Engineer's Manual of Marine Boiler and Feed-Water Treatment also discusses each type of pages 62-66. You should know these types and be able to explain the causes of each.

FACTORS CAUSING CORROSION

Oxygen
Carbon Dioxide
Acid
Caustic
Hydrogen
Ammonia
Mechanical

SLIDE #7

OXYGEN CORROSION

1. Removes passive coatings.
2. Prevents formation of massive coatings.
3. Encourages formation of soluble corrosion products, continually exposing new surface to attack.

SLIDE #8

Advance to slide number eight. We have already mentioned how oxygen (O) removes the protective coatings. We also mentioned that the presence of oxygen (O) will prevent the formation of protective coatings by causing the formation of soluble corrosion products, which go into solution and expose a new layer of metal atoms to attack. The oxygen (O) is removed from the water in two ways.

Look at slide number nine. The oxygen can be removed physically in the deaerating heater by raising the temperature of the water almost to boiling. This occurs because solubility of the dissolved gas is lowered by increasing temperature. By adding either of the two scavangers the remaining oxygen will be used up chemically before it can cause corrosion. We no longer actually measure to see if oxygen is present in boiler water, although such tests were commonplace in the past. Today we simply measure the residual of the scavanger, either sulfite or hydrazine (NH_2NH_2), as we did in Module D-2.

OXYGEN REMOVAL

1. Physically - deaerating heater.
2. Chemically - scavangers.

SODIUM SULFITE:
$Na_2SO_3 + O_2 \longrightarrow Na_2SO_4$

HYDRAZINE:
$N_2H_4 + O_2 \longrightarrow H_2O + N_2$

SLIDE #9

Advance to slide number ten. Among the salts in sea water are carbonates and bicarbonates. In the evaporator they break down to form sodium hydroxide (NaOH) and the gas carbon dioxide (CO_2). The carbon dioxide (CO_2) is carried over with the water (H_2O) vapor and redissolves in the condensate.

SOURCE OF CO_2 in BOILING WATER

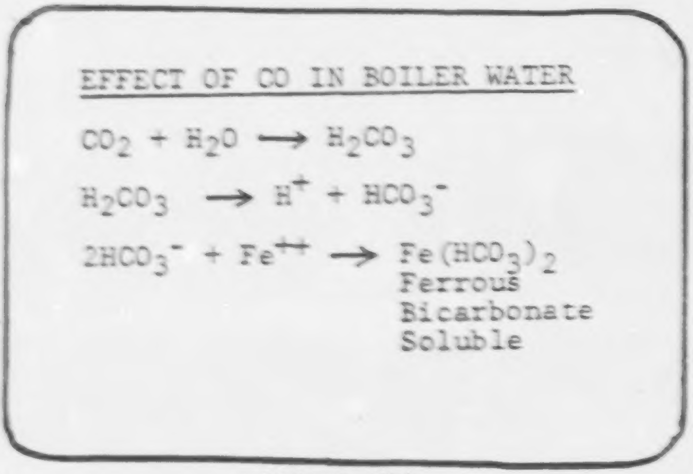
1. Carbonates in sea water break down in the evaporator and carbon dioxide is carried over into the make-up feedwater.

CARBONATE:
$NaHCO_3 \longrightarrow NaOH + CO_2\uparrow$

BICARBONATE
$Na_2CO_3 \longrightarrow NaOH + CO_2\uparrow$

SLIDE #10

Look at slide number eleven. Once the carbon dioxide (CO_2) is in the feedwater it reacts with the water (H_2O) to form an acid. That acid is carbonic acid. Carbonic acid ionizes and reacts with the iron to form ferrous bicarbonate which is highly soluble, continually exposing a new unprotected surface to corrosion.



EFFECT OF CO IN BOILER WATER

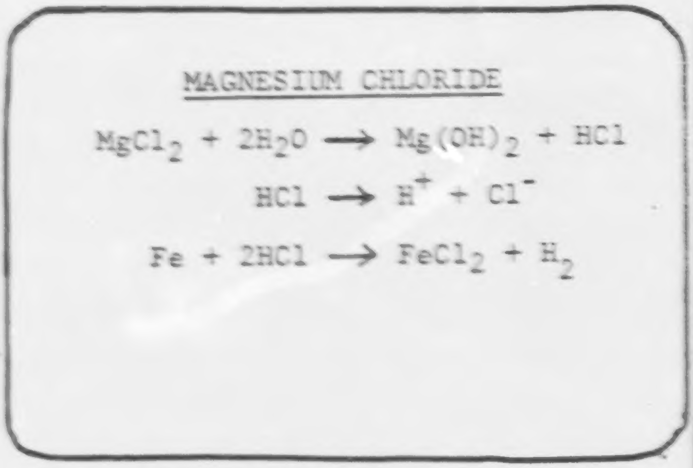
$CO_2 + H_2O \longrightarrow H_2CO_3$

$H_2CO_3 \longrightarrow H^+ + HCO_3^-$

$2HCO_3^- + Fe^{++} \longrightarrow Fe(HCO_3)_2$ Ferrous Bicarbonate Soluble

SLIDE #11

Look at slide number twelve. Acid corrosion occurs when the boiler water becomes acidic, that is, when the pH drops below 7 or when there are more hydrogen ions (H^+) in the water than hydroxyl ions (OH^+). If any magnesium chloride ($MgCl_2$) should get into the boiler water, either by carryover in the evaporator or through leakage in the condensers, the water quickly becomes acidic. The magnesium (Mg) forms a precipitate with the hydroxal ion (OH^-) removing it from the solution, leaving an excess of hydrogen ions, an acidic situation.



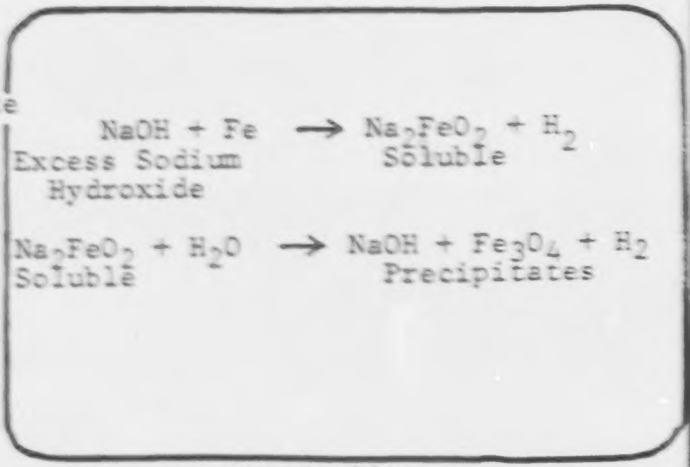
MAGNESIUM CHLORIDE

$MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 + HCl$

$HCl \longrightarrow H^+ + Cl^-$

$Fe + 2HCl \longrightarrow FeCl_2 + H_2$

SLIDE #12



$NaOH + Fe \longrightarrow Na_2FeO_2 + H_2$
Excess Sodium Hydroxide — Soluble

$Na_2FeO_2 + H_2O \longrightarrow NaOH + Fe_3O_4 + H_2$
Soluble — Precipitates

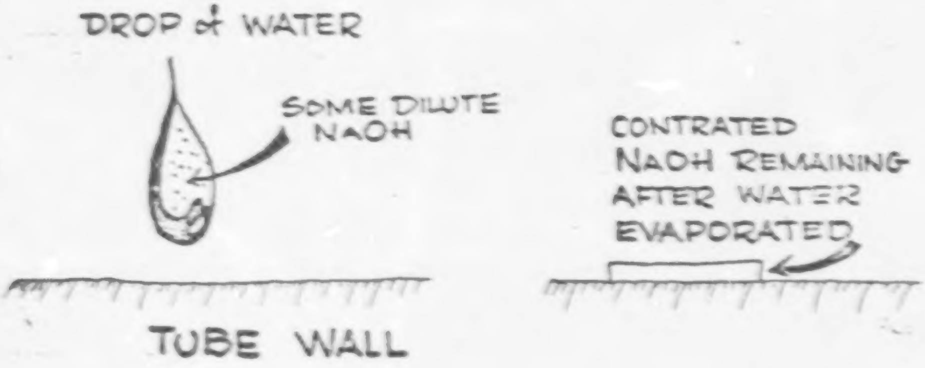
SLIDE #13

Now advance your carrousel to slide number thirteen. Sodium hydroxide is added to the boiler water in order to maintain the pH at the proper levels. This prevents corrosion and enhances the formation of protective coatings. If, however, too much sodium hydroxide (NaOH) is present caustic corrosion can occur. The sodium hydroxide (NaOH) reacts with the iron (Fe) to form a soluble sodium iron oxide which once dissolved will change into magnetite, BUT NOT AS A PROTECTIVE COATING, only as a precipitate of loose porous magnetite.

See Page 224A - Following

SLIDE #14

Look at slide number fourteen. If conditions occur in the boiler where a water drop can splash on the hot dry surface of a tube which is not filled with water, the drop evaporates. But as it evaporates, in the place where it hits, the concentration of sodium hydroxide (NaOH) increases until it reaches the damaging stage. In the elective unit on corrosion control in high pressure boilers we will discuss the methods used to prevent the concentration of sodium hydroxide (NaOH) from increasing. These are known as coordinated phosphate controls.


DROP of WATER
SOME DILUTE NAOH
CONTRATED NAOH REMAINING AFTER WATER EVAPORATED
TUBE WALL

SLIDE #14

Look at slide number fifteen. Hydrogen damage, or hydrogen embrittlement is caused by hydrogen molecules which work their way into the intersticies between the crystals of the iron (Fe) alloy. The hydrogen (H) combines with carbon (C) atoms to form a molecule of methane (CH_4) which is physically larger than the hydrogen (H) and carbon (C) taken separately. The change in size builds up a pressure which eventually causes a minute fracture between the crystals. With enough fractures, the metal cracks as though brittle. Hydrogen (H) damage can take place in a matter of hours after a condenser leak.

See Page 225A - Following

SLIDE #15

Look at slide number sixteen. We add hydrazine (NH_2NH_2) to the boiler water as an oxygen (O) scavanger. If, however, we add too much some carries over with the steam and redissolves in the water in the condenser. If the pH in the condenser rises above the value of 9, then the ammonia reacts with the copper in the condenser tubing to form soluble products. And remember, when the

AMMONIA CORROSION:

$N_2H_4 + O_2 \rightarrow H_2O + N_2$

$N_2H_4 \rightarrow NH_3 + N_2$

IN CONDENSERS:

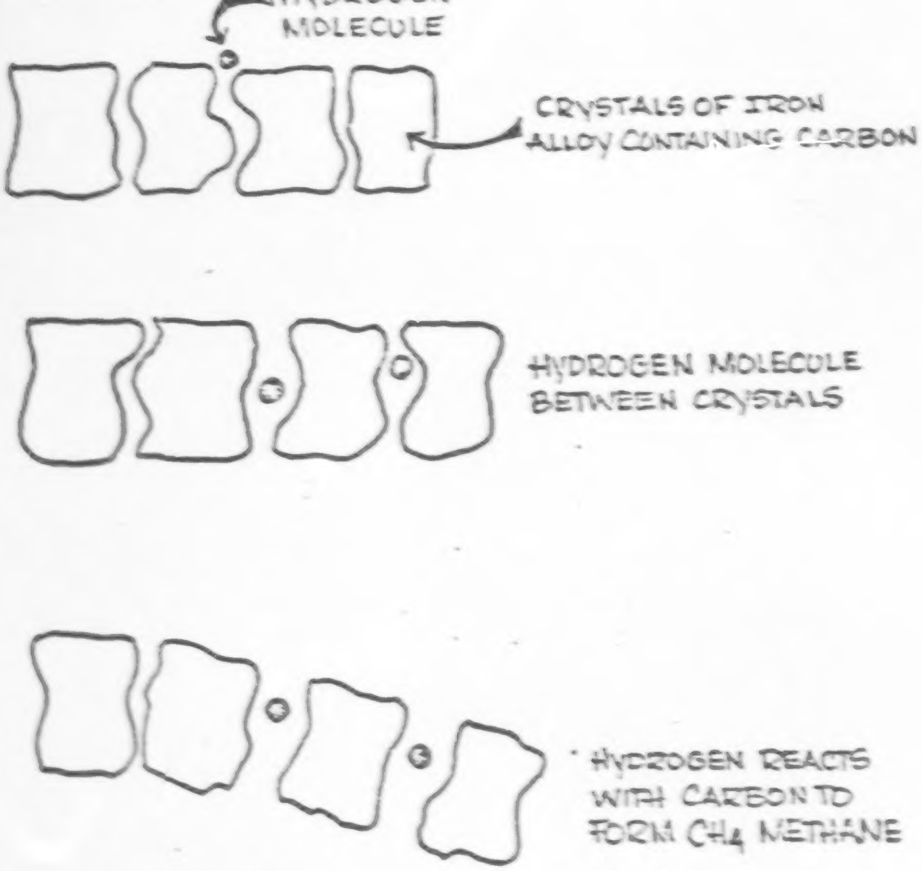
$NH_3 + H_2O \rightarrow NH_4OH$

NH_4OH increases the pH

pH 8.3 - 9.0 OK

above 9.0 the ammonia reacts with copper to form soluble products.

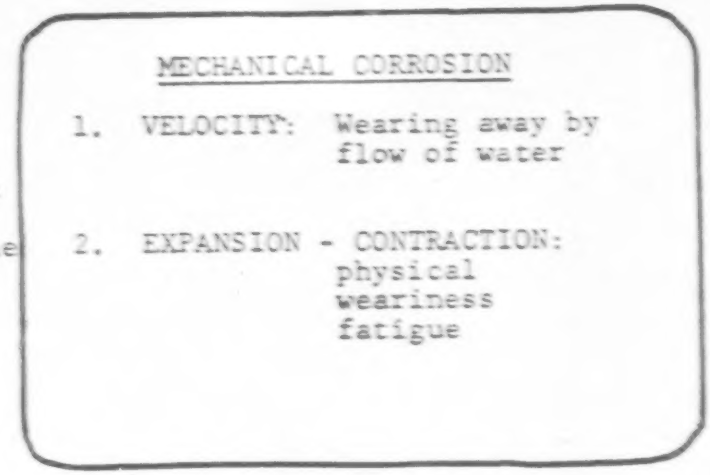
SLIDE #16


HYDROGEN MOLECULE
CRYSTALS OF IRON ALLOY CONTAINING CARBON
HYDROGEN MOLECULE BETWEEN CRYSTALS
HYDROGEN REACTS WITH CARBON TO FORM CH4 METHANE

HYDROGEN EMBRITTLEMENT

SLIDE #15

metal forms soluble products it is undergoing corrosion.



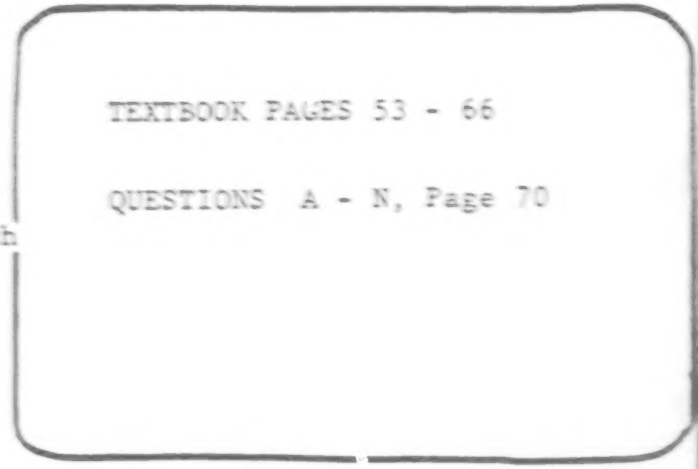
MECHANICAL CORROSION

1. VELOCITY: Wearing away by flow of water

2. EXPANSION - CONTRACTION: physical weariness fatigue

SLIDE #17

Advance your carrousel to slide number seventeen. You may have seen the Grand Canyon and been awed by the realization that this mile deep excavation was effected by running water. In a boiler the water is always moving, circulating, and it too, wears away the walls of its container, especially where these walls force a change in the direction of its flow. Any loose scale may be swept away, exposing fresh surface to corrosion. This effect is called velocity corrosion, or sometimes referred to as just velocity. Another mechanical cause of corrosion is the constant fluctuations of temperature, and pressure, which induces metal fatigue from recurring stresses. Metal fatigue is what happens to a paper clip that is bent back and forth until it breaks. Airplane wings structures crack from this cause and so also do boiler tubes weaken.



TEXTBOOK PAGES 53 - 66

QUESTIONS A - N, Page 70

SLIDE #18

Look at slide number eighteen. The textbook, Engineer's Manual of

Marine Boiler and Feedwater Treatment covers all of this material on pages 53 through 66. See if you can answer questions A through N on page 70. If you can, you have met the objectives of the module and further, should be able to pass the end of module exam.

MODULE C - 4 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the MODULE C-4 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE C-4 as well as to the completion of the problem set. Those pages are: 139-142, 175, 179, 196, 221-226, 240, 251-259.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown.

(Read Across)

Page	Problem
148	2
181	8
242	14
261	3

MODULE C-4 PROBLEM SET SOLUTIONS

Page	Problem	
148	(2)	F, 9 electrons Ca, 20 electrons Fe, 26 electrons Es, 99 electrons
181	(8)	a. $K + H_2 \longrightarrow 2KH$ b. $2Cs + 2H_2O \longrightarrow 2CsOH + H_2$ c. $2Sb + 3Cl_2 \longrightarrow 2SbCl_3$ d. No Reaction e. $2Na + Se \longrightarrow Na_2Se$ f. $Cl_2 + 2KI \longrightarrow I_2 + 2KCl$ g. No Reaction h. $2NaCl + 2H_2 \longrightarrow 2NaOH + H_2 + Cl_2$
242	(14)	The strength of an acid refers to its ability to give up a proton while the strength of a base refers to its ability to accept a proton. No reactions would be expected. However, if H_2SO_4 were mixed with NaCl, a reaction would be expected.
261	(3)	a. $Sn^{4+} + 2e^- \longrightarrow Sn^{2+}$ b. $Hg^{2+} + 2e^- \longrightarrow 2Hg$ c. $O_3 + 2e^- \longrightarrow O_2 + O^{2-}$ d. $H_2O_2 + 2H_3O^+ + 2e^- \longrightarrow 4H_2O$ e. $HClO + H_3O^+ + e^- \longrightarrow Cl^- + H_2O$ f. $I_2 + 12OH^- \longrightarrow 2IO_3 + 6H_2O + 10e^-$ g. $NO_2^- + 3H_2O \longrightarrow NO_3^- + 2H_3O^+ + 2e^-$

Name ____________________

MODULE C4 - 1 EXAMINATION

1. Describe the process of embrittlement. Use a drawing to help.

2. What is exfoliation?

3. Name the two oxygen scavengers in common use in the maritime industry.

4. In what part of the plant is ammonia corrosion most apt to occur?

5. Where does the ammonia come from? Write the equation.

6. Most corrosion is an electrochemical process. Explain how the TDS level affects the rate of corrosion.

7. A protective coating formed on the metal is called passivation. Name two layers formed on the metal to protect it in the boiler.

8. How is the carbon dioxide in the make up feed water removed?

9. How does the pH contribute to corrosion damage?

10. Not all corrosion is due to chemical causes. Name two mechanical causes of corrosion.

MODULE C4 - 1 EXAMINATION SOLUTION SET

1. Embrittlement is an effect of corrosion that changes the physical properties of a metal. During the process of embrittlement, the metal looses its normal strength and ductility and becomes brittle and weak. Embrittlement cannot be seen by inspecting a boiler tube that has not failed. However, an embrittled tube that has failed will have a crystallized appearance at the edge of the point of failure and there will usually be no evidence of buldging.

2. Exfoliation or dealloying is a selective reaction of only one of the metals in a metal alloy. It generally occurs in feedwater heaters where nickel is selectively oxidized from the copper-nickel alloy tubing leaving layers of copper metal and nickel oxide. As occurs with this and other alloys, a soft spot is created.

3. Sulfite and hydrazine.

4. Ammonia corrosion is likely to occur in the copper tubing of a condenser and in feedwater heaters. This usually occurs in the presence of large amounts of ammonia and oxygen.

5. Ammonia or amines are used to maintain the optimum pH conditions in the feedwater systems. Excess amines such as hydrazine leave a boiler drum with the steam they will decompose at the high temperatures in a superheater according to the following reaction:

$$3N_2H_4 \xrightarrow{heat} 3NH_3 + N_2$$

When steam condenses in the surface condenser, the ammonia gas that has formed by decomposition becomes dissolved in the condensate.

$$NH_3 + H_2O \longrightarrow NH_4OH$$

6. The higher the level of total dissolved solids, normally, the more rapid will be the rate of corrosion.

7. Magnetite (Fe_3O_4) and cuprous oxide (Cu_2O).

8. One way is by running the feedwater through a deaerating heater.

9. If the pH is too low an excess of H^+ ion is present and acid corrosion occurs. On the other hand, excessive amounts of OH^- or an excessively high pH and caustic corrosion occurs.

10. Velocity and turbulence of moving boiler water.

Name ______________________

MODULE C4 - 2 EXAMINATION

1. List and define the factors causing corrosion.

2. Why is corrosion considered an electrochemical process?

3. Write the basic reactions that take place at the cathode and anode in the corrosion process:

4. How is the raw water carbonate and bicarbonate alkalinity related to corrosion in the power generation process?

5. What is the function of the deaerating heater?

6. Why is a low pH condition to be avoided?

7. What is hydrogen damage?

8. What is the role of oxygen in the corrosion process of copper-bearing alloys?

MODULE C4 - 2 EXAMINATION SOLUTION SET

1. a. Oxygen corrosion - caused by the presence of oxygen in the boiler water.

   b. Carbon dioxide corrosion -- caused by CO_2 in the boiler water. The CO_2 comes from the breakdown of carbonates and bicarbonates in the feedwater.

   c. Acid corrosion -- magnesium ions in feedwater react with the phosphates and hydroxyl ions in the boiler water. Magnesium hydroxyde then precipitates causing the pH to fall. The acid then is free to attack the metals in the boiler system.

   d. Caustic corrosion -- this is corrosion caused by the presence of sodium hydroxide ions -- excess sodium hydroxide ions.

   e. Ammonia corrosion -- this type of corrosion occurs with the presence of excess amounts of ammonia and oxygen.

   f. Mechanical corrosion -- this is corrosion caused by the erosion of surface metal due to the velocity or turbulence of feedwater.

2. Corrosion is considered to be an electrochemical process because it involves the movement of electrons from one substance to another.

3. Anode reaction: $Fe \longrightarrow Fe^{++} + 2e$
   Cathode reaction: $2e + 2H^{+} \longrightarrow 2H \longrightarrow 1H_2$

4. Heat in boilers causes carbonates and bicarbonates in the brine to breakdown causing CO_2 to occur. The CO_2 that is formed leaves the evaporator with the steam and causes corrosion of the condensate return lines. The following reactions are relative to this process:

$$NaHCO_3 \xrightarrow{heat} NaOH + CO_2\uparrow \qquad Na_2CO_3 + H_2O \xrightarrow{heat} 2NaOH + CO_2\uparrow$$

$$CO_2 + H_2O \longrightarrow H_2CO_3 \qquad \text{OR} \qquad CO_2 + H_2O \longrightarrow H^+\ HCO_3^-$$

$$Fe + 2H_2CO_3 \longrightarrow Fe(HCO_3)_2 + H_2\uparrow$$

5. The deaerator is used to remove dissolved oxygen and other gases from the condensate.

6. Low pH (around 4.0) results in the following (magnesium is present in intake seawater)

$$MgCl_2 + 2H_2O \xrightarrow{heat} Mg(OH)_2\downarrow + 2HCl$$

$$Fe + 2HCl \longrightarrow Fe(Cl)_2 + H_2$$

reaction. The result is hydrochloric acid attack upon metal surfaces.

7. Hydrogen damage is a form of attack which damages the internal structure of the metal causing it to become brittle.

8. The presence of oxygen accelerates corrosion by cathodic depolarization and by destroying the passivity of copper surfaces.

Name ______________________

MODULE C4 - 3 EXAMINATION

1. What is corrosion? Name and define the factors causing corrosion.

2. Write the basic reactions that take place at the cathode and anode in corrosion:

3. What is the function of the deaerating heater?

4. What is hydrogen damage and why is it difficult to prevent?

5. Explain how the different types of corrosion can be minimized by proper water treatment.

6. What is a chemical hideout?

MODULE C4 - 3 EXAMINATION SOLUTION SET

1. Corrosion is the slow dissolution of metal in water. Also, see Module C4-2 examination solution set, question #1.

2. Anode reaction: $Fe \rightarrow Fe^{++} + 2e$
   Cathode reaction: $2e + 2H^{+} \rightarrow 2H \rightarrow 1H_2$

3. The deaerator is used to remove dissolved oxygen and other gases from the condensate.

4. Hydrogen damage is often difficult to control because it occurs very rapidly. Also, it is a form of attack which damages the internal structure of the metal causing it to become brittle.

5. Proper water treatment will minimize the contaminants contained in feedwater. This is done by distillation, deaeration, addition of oxygen scavangers, maintenance of the proper pH range, . The closer the feedwater is to being pure, the less and slower the rate of corrosion will be.

6. Chemical hideout is characterized by an abnormally fast loss of phosphate residual from boiler water during normal steaming and the occurrence of a high phosphate residual when a boiler is shut down or operated at a low steaming rate.

Name ____________________________

MODULE C4 - 4 EXAMINATION

1. Describe the process of hydrogen embrittlement. Use a diagram if necessary.

2. Name the two oxygen scavangers used in marine industry and write their equations.

3. The Bramine test measures the pH of the condensate. The pH of the condensate is due to the presence of ammonium hydroxide. Where does the ammonia come from?

4. A protective layer on a metal surface is called polarization. Name the two protective layers formed in the boiler.

5. Not all corrosion is due to chemical causes. Name two mechanical causes.

6. What does the TDS have to do with corrosion?

MODULE C4 - 4 EXAMINATION SOLUTION SET

1. Embrittlement is an effect of corrosion that changes the physical properties of a metal. During the process of embrittlement, the metal looses its normal strength and ductility and becomes brittle and weak. Embrittlement cannot be seen by inspecting a boiler tube that has not failed. However, an embrittled tube that has failed will have a crystallized appearance at the edge of the point of failure and there will usually be no evidence of buldging.

2. Sulfite and hydrazine.

3. Ammonia or amines are used to maintain the optimum pH conditions in the feedwater systems. Excess amines such as hydrazine leave a boiler drum with the steam they will decompose at the high temperatures in a superheater according to the following reaction:

$$3N_2H_4 \xrightarrow{heat} 3NH_3 + N_2$$

When steam condenses in the surface condenser, the ammonia gas that has formed by decomposition becomes dissolved in the condensate.

$$NH_3 + H_2O \longrightarrow NH_4OH$$

4. Magnetite (Fe_3O_4) and cuprous oxide (Cu_2O).

5. Velocity and turbulence of moving boiler water.

6. The higher the level of total dissolved solids, normally, the more rapid will be the rate of corrosion.

Name ________________________

MODULE C4 - 5 EXAMINATION

1. What is the relationship between pH and corrosion?

2. Define the following:

   a. Exfoliation

   b. Hydrogen embrittlement

   c. Chemical hideout

3. What is the function of an oxygen scavenger?

4. Explain the relationship between O_2 and Cu alloy corrosion.

5. What are three types of deposits found in marine steam generating plants?

6. How can protective layers be formed in marine boilers?

MODULE C4 - 5 EXAMINATION SOLUTION SET

1. If the pH is too low an excess of H^+ ion is present and acid corrosion occurs. On the other hand, excessive amounts of OH^- or an excessively high pH and caustic corrosion occurs.

2. a. Exfoliation or dealloying is a selective reaction of only one of the metals in a metal alloy. It generally occurs in feedwater heaters where nickel is selectively oxidized from the copper-nickel alloy tubing leaving layers of copper metal and nickel oxide. As occurs with this and other alloys, a soft spot is created.

   b. Embrittlement is an effect of corrosion that changes the physical properties of a metal. Some corrosion reactions cause metals to loose their normal strength and ductility and become brittle and weak.

   c. Chemical hideout is characterized by an abnormally fast loss of phosphate residual from boiler water during normal steaming and the occurrence of a high phosphate residual when a boiler is shut down or operated at a low steaming rate.

3. An oxygen scavenger is a chemical which will remove dissolved oxygen from water.

4. Oxygen in boiler water causes corrosion by cathode depolarization and by destroying the passivity of copper surfaces.

5. Corrosion product deposits, scale deposits, sludge deposits.

6. In the absence of oxygen, ferrous ions produced at the anode react with hydroxyl ions forming ferrous hydroxide. The process continues until Fe_3O_4 (magnetite) is formed. Fe_3O_4 forms a protective coating. In copper systems a protective oxide occurs at the anode. That coating is Cu_2O (cuprous oxide).

P. 241

Name ______________________

MODULE C4 - 6 EXAMINATION

1. How might a battery be likened to the corrosive systems found in marine boilers?

2. What have suspended sludges and solids to do with boiler water corrosion?

3. What is hydrogen damage?

4. How may corrosion be minimized in shipboard boilers?

5. What is meant by feedwater contamination?

6. What is the end result of long term corrosion of boiler tubes?

MODULE C4 - 6 EXAMINATION SOLUTION SET

1. A battery contains an anode, cathode, and an electrolyte. Under these conditions, electrons will flow and the physical properties of the electrodes will eventually change. This essentially is the same process which occurs in boiler corrosion. In boilers, the electrodes need not be dissimilar electrodes but different areas of the same piece of metal.

2. Suspended sludges and solids are the result of boiler corrosion and improper boiler water treatment. Excess deposits can cause overheating and additional corrosion problems.

3. Hydrogen damage is a form of attack which damages the internal structure of the metal causing it to become brittle.

4. Corrosion may be minimized by proper feedwater treatment.

5. Feedwater contamination means that the feedwater contains such things as dissolved gases, etc., which will cause or aid boiler corrosion.

6. Total breakdown of the tubes. The tubes may rupture or they may become occluded by deposits.

Name ______________________

MODULE C4 - 7 EXAMINATION

1. Define the following terms:

   a. exfoliation

   b. oxygen scavenger

   c. chemical hideout

   d. H damage

2. Why is corrosion to be an electrochemical process?

3. What is the relationship between suspended sludge and solids in boiler feedwater and the need for feedwater treatment?

4. In feedwater treatment, what is the function of a deaerating heater?

5. Write at least one reaction which takes place at the anode and one which takes place at the cathode during the corrosive process.

MODULE C4 - 7 EXAMINATION SOLUTION SET

1. Exfoliation or dealloying is a selective reaction of only one of the metals in a metal alloy. It generally occurs in feedwater heaters where nickel is selectively oxidized from the copper-nickel alloy tubing leaving layers of copper metal and nickel oxide. As occurs with this and other alloys, a soft spot is created.

2. An oxygen scavenger is a chemical which will remove dissolved oxygen from water.

3. Suspended sludges and solids are the result of boiler corrosion and improper boiler water treatment. Excess deposits can cause overheating and additional corrosion problems.

4. The deaerator is used to remove dissolved oxygen and other gases from the condensate.

5. Anode reaction: $Fe \longrightarrow Fe^{++} + 2e$
Cathode reaction: $2e + 2H^{+} \longrightarrow 2H \longrightarrow 1H_2$

Name ______________________

MODULE C4 - 8 EXAMINATION

1. Name three types of deposits which are found in steam generating plants.

2. Relate CO_3 and HCO_3 to corrosion in boilers.

3. What is H damage?

4. Name two mechanical causes of corrosion.

5. What is ammonia corrosion and where in a marine steam plant is it likely to occur?

6. What is the relationship between pH and corrosion?

MODULE C4 - 8 EXAMINATION SOLUTION SET

1. Corrosion product deposits, scale deposits, sludge deposits.

2. Heat in boilers causes carbonates and bicarbonates in the brine to breakdown causing CO_2 to occur. The CO_2 that is formed leaves the evaporator with the steam and causes corrosion of the condensate return lines. The following reactions are relative to this process:

$$NaHCO_3 \xrightarrow{heat} NaOH + CO_2\uparrow \qquad Na_2CO_3 + H_2O \xrightarrow{heat} 2NaOH + CO_2\uparrow$$

$$CO_2 + H_2O \longrightarrow H_2CO_3 \qquad \text{OR} \qquad CO_2 + H_2O \longrightarrow H^+ \; HCO_3^-$$

$$Fe + 2H_2CO_3 \longrightarrow Fe(HCO_3)_2 + H_2\uparrow$$

3. Hydrogen damage is a form of attack which damages the internal structure of the metal causing it to become brittle.

4. Mechanical corrosion is corrosion caused by the erosion of surface metal due to the velocity or turbulence of feedwater.

5. Ammonia corrosion is likely to occur in the copper tubing of a condenser and in feedwater heaters. This usually occurs in the presence of large amounts of ammonia and oxygen.

Ammonia or amines are used to maintain the optimum pH conditions in the feedwater systems. Excess amines such as hydrazine leave a boiler drum with the steam they will decompose at the high temperatures in a superheater according to the following reaction:

$$3N_2H_4 \xrightarrow{heat} 3NH_3 + N_2$$

When steam condenses in the surface condenser, the ammonia gas that has formed by decomposition becomes dissolved in the condensate.

$$NH_3 + H_2O \longrightarrow NH_4OH$$

6. If the pH is too low an excess of H^+ ion is present and acid corrosion occurs. On the other hand, excessive amounts of OH^- or an excessively high pH and caustic corrosion occurs.

Name ______________________

MODULE C4 - 9 EXAMINATION

1. What is the function of an oxygen scavenger?

2. What is the role O_2 plays in copper alloy contamination?

3. Define the following terms:
   a. hydrogen embrittlement
   b. chemical hideout
   c. H damage
   d. deaerating heater
   e. electrochemical corrosion
   f. passivation

MODULE C4 - 9 EXAMINATION SOLUTION SET

1. An oxygen scavenger is a chemical which will remove dissolved oxygen from water.

2. Oxygen in boiler water causes corrosion by cathode depolarization and by destroying the passivity of copper surfaces.

3. a. Embrittlement is an effect of corrosion that changes the physical properties of a metal. During the process of embrittlement, the metal looses its normal strength and ductility and becomes brittle and weak. Embrittlement cannot be seen by inspecting a boiler tube that has not failed. However, an embrittled tube that has failed will have a crystallized appearance at the edge of the point of failure and there will usually be no evidence of buldging.

   b. Chemical hideout is characterized by an abnormally fast loss of phosphate residual from boiler water during normal steaming and the occurrence of a high phosphate residual when a boiler is shut down or operated at a low steaming rate.

   c. Hydrogen damage is a form of attack which damages the internal structure of the metal causing it to become brittle.

   d. The deaerator is used to remove dissolved oxygen and other gases from the condensate.

   e. Corrosion is considered to be an electrochemical process because it involves the movement of electrons from one substance to another.

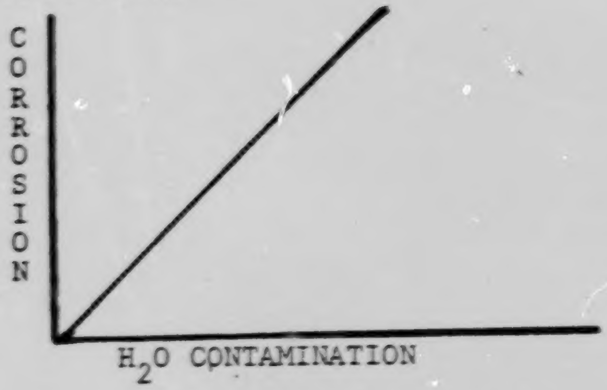
   f. Magnetite (Fe_3O_4) and cuprous oxide (Cu_2O).

Name ____________________

MODULE C4 - 10 EXAMINATION

1. What is the relationship between low pH and corrosion?

2. Interpret the following graph:



3. What would you expect to be the relationship between extensive feedwater treatment and corrosion?

4. As the amount of dissolved O_2 increases in feedwater in contact with copper alloy parts, the Cu alloy parts would be expected to:

5. Define the following terms:

   a. passivation

   b. exfoliation

MODULE C4 - 10 EXAMINATION SOLUTION SET

1. If the pH is too low an excess of H^+ ion is present and acid corrosion occurs. On the other hand, excessive amounts of OH^- or an excessively high pH and caustic corrosion occurs.

2. The graph indicates that the amount of corrosion is directly proportional to the magnitude of water contamination.

3. The more extensive the water treatment, the lower will be the amount of corrosion and the rate of corrosion.

4. Corrode more rapidly except that originally one might expect to see the formation of a protective cuprous oxide coating.

5. a. Magnetite (Fe_3O_4) and cuprous oxide (Cu_2O).

   b. Embrittlement is an effect of corrosion that changes the physical properties of a metal. During the process of embrittlement, the metal looses its normal strength and ductility and becomes brittle and weak. Embrittlement cannot be seen by inspecting a boiler tube that has not failed. However, an embrittled tube that has failed will have a crystallized appearance at the edge of the point of failure and there will usually be no evidence of buldging.

CHEMICAL REACTIONS

Module B-1, Chemical Reactions, deals with the following concepts: the relationship between energy and the phases of matter (solid, liquid, gas); heats of reaction; catalysis; entropy; open and closed chemical systems; the Law of Mass Action; equilibrium constants; and hydrogen ion concentrations (pH).

As a result of studying this module, the student will be able to define the various terms related to the concepts, explain the concepts in detail, and apply the concepts to new situations.

In this module you will again study chemical reactions. This module considers energy effects on reaction rates and equilibrium.

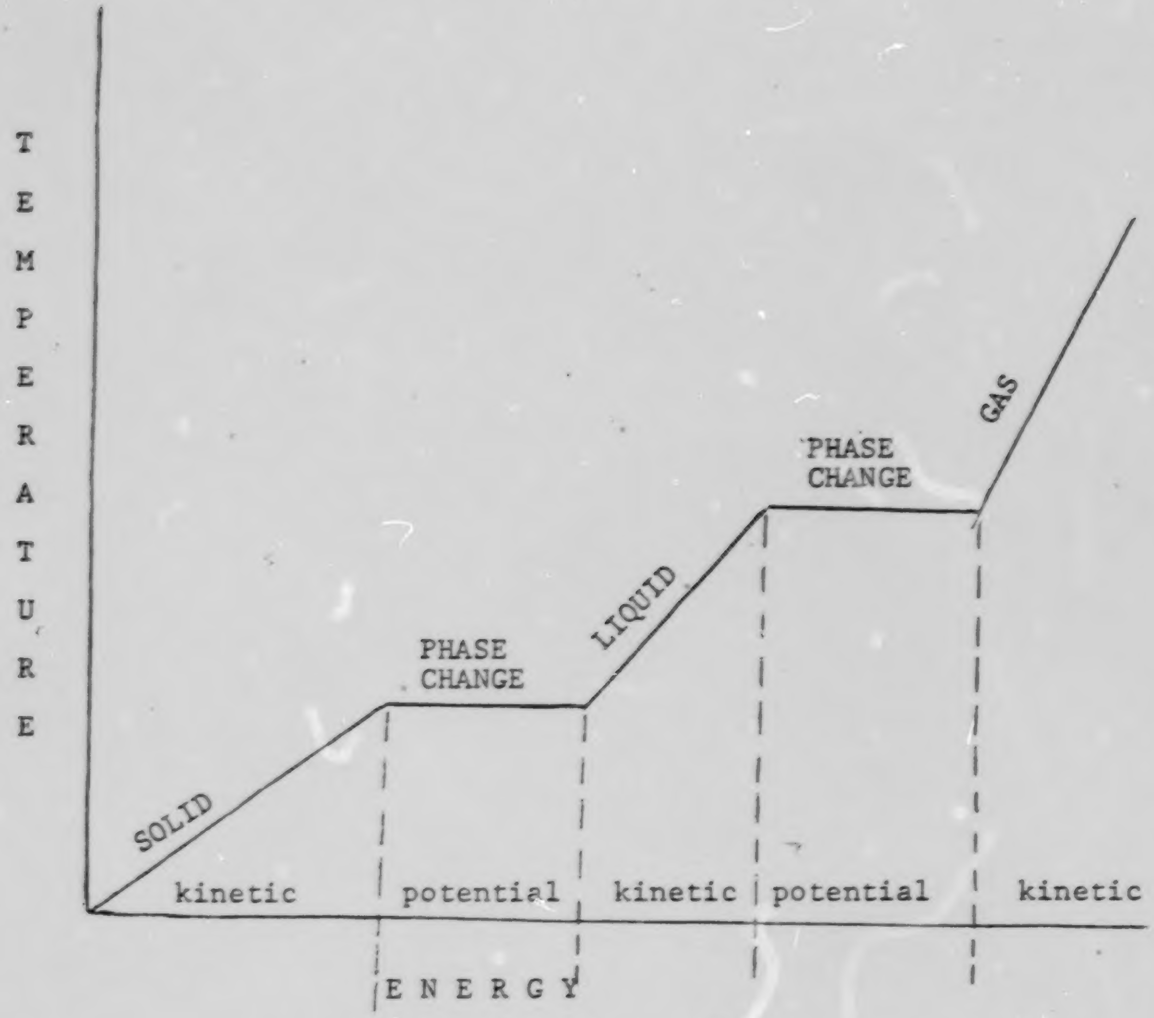
If you will recall from your physics courses, heat is the energy of molecules and includes potential as well as kinetic energy. Temperature is only a measure of kinetic energy.

Advance your slide carrousel to slide number one.

See Page 251A - Following

SLIDE #1

PHASE ENERGY RELATION



SLIDE #1

If a solid, such as ice, is supplied with heat energy, its temperature first rises indicating that the speed of molecules or kinetic energy increases. At the melting point, heat is absorbed without a temperature increase until all of the solid has melted. The energy becomes potential energy of the molecules. Further application of heat increases the temperature again until the next phase change. Heat is both energy of movement of individual molecules (kinetic) and energy among the molecules (potential).

Energy is also bound up within molecules. The source of this internal energy is the energy involved in the formation of the bonds which hold the molecule together. It is potential energy.

If, in the formation of a chemical bond, energy is released and a stable bond results, the energy is taken away from the reaction as heat and dissipates into the surroundings.

Look at slide number two. When we write equations for reactions we

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O + \text{Heat}$

The heat of reaction is because heat leaves the reaction.

SLIDE #2

usually leave out the heat energy, or enthalpy, which is either a reactant or product. We have included it here.

Since the heat, ΔH, is a product in the reaction and leaves the reaction, it is considered to have a negative sign. Conversely, heat put into or added to a reaction would have a positive sign.

Look at slide number three. The amount of heat gained or lost in a chemical reaction can be predicted. Slide number three lists the heats of formation per mole. Per mole means per mole of substance formed as the result of a chemical reaction.

REACTION REACTION	ΔH_f ENTHALPY
$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$ (L) (G)	-68.3 Kcal/mol
$C + 2H_2 \longrightarrow CH_4$ methane	-17.9
$3C + 4H_2 \longrightarrow C_3H_8$ propane	-24.8
$C + O_2 \longrightarrow CO_2$	-94.05

SLIDE #3

Can you solve the following problem? Suppose hydrogen is being burned at the rate of 10 grams per minute, how much heat is being produced per minute?

Look at slide number four. Hydrogen burns to form water. Water has a heat of formation (ΔH_f) of 68.32 K cal/mol if the vapor is allowed to condense. If more than 1 mole of water is formed, the heat of formation will be multiplied by the number of moles of water formed.

See Page 253A - Following

SLIDE #4

Elements do not have heats of

$$H_2 + \frac{1}{2} O_2 \longrightarrow 1\, H_2O + \overset{\Delta H_f}{(-68.32 \text{ KCal/Mol})}$$

↑ ARRANGE SO THAT THIS COEFFICIENT IS 1

IF THE COEFFICIENT OF THE PRODUCT IS OTHER THAN 1, MULTIPLY THE HEAT BY THE SAME COEFFICIENT

WE HAVE 10 G H_2 PER MINUTE

$$N_{H_2} = \text{WT}/\text{Mol WT} = \frac{10\text{ G}}{2\text{ G}/\text{Mol}} = 5 \text{ mols}$$

$$5\, H_2 + 5\left(\tfrac{1}{2}\right) O_2 \longrightarrow 5\, H_2O + 5(-68.32)$$

$$\Delta H_f = 5\,(-68.32)$$

$$= -341.6 \text{ K Cal/MIN}$$

SLIDE #4

formation since they are the starting point; only compounds have heats of formation.

Following the calculation of slide number four, it is possible to calculate the number of moles of hydrogen burned per minute. This calculation yields 5 moles. Since, in the balanced equation, the number of hydrogen and water are equal, the number of moles of water must be equal to 5. Therefore, 5 times the molar heat of formation of water is released per minute.

If compounds are involved as reactants, the calculation is somewhat more complex. The heats of formation of the reacting compounds must be subtracted from the heats of formation of the products.

Advance to slide number five. Methane burns to form CO_2 + water vapor. If 48 grams of methane is burned per minute, how much heat will be produced?

See Page 254A - Following

SLIDE #5

First, write the balanced equation. The amount of heat involved in the balanced equation can then be calculated. This is done by adding the heat of formation of the products and

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{HEAT}$$

HEAT INVOLVED : $\underbrace{1(-17.9) + 2(0)}_{\text{ADD}} \rightarrow \underbrace{1(-94.05) + 2(57.8)}_{\text{ADD}}$

TOTAL HEAT : HEAT OF PRODUCTS MINUS HEAT OF REACTANTS

$$= -209.6 - (-17.9) = -191.7$$

NOTE : EQUATION MUST BE BALANCED

48 GRAMS METHANE : $N = wt/_{M.W.} = 48\,G./16\,G/mol = 3$ mols

THEREFORE MULTIPLY EVERYTHING IN THE BALANCED EQUATION BY 3, INCLUDING HEAT

$$\Delta H = 3(-191.7 \text{ K cal}) = 575.1 \text{ K cal}$$

Released

subtracting the heat of formation of the reactants.

In this case, we have 1 mole of methane whose heat of formation is -17.9 Kcal/mol (since oxygen is an element, it has no heat of formation). Therefore, the total heat of formation for the reactants is -17.9 Kcal.

The heat of formation of 1 mole of CO_2 is -94 Kcal and 2 moles of water is 2 times -57.8 Kcal for a total of -209 Kcal. The resulting heat of reaction is then -191.7 Kcal.

Recall that 48 grams of methane per minute was being burned and 48 grams of methane is 3 moles of methane. In the balanced equation the coefficient of methane was 1. Therefore, everything needs to be multiplied by 3. The net heat produced is 3 times -191.7 or -575.1 Kcal/min.

Now look at slide number six. Propane burns to form carbon dioxide and water vapor as indicated in the equation. The equation is not balanced. If the rate of combustion is 22 grams per minute, how much heat is produced per minute?

$\_C_3H_8 + \_O_2 \rightarrow \_CO_2 + \_H_2O$ (gas)
propane

SLIDE #6

The first thing you must do in order

to solve the problem is to balance the equation. The heats of formation are listed on slide number three. The problem is worked out on slide number seven, but give it an honest try before consulting slide number seven.

See Page 256A - Following

SLIDE #7

Advance your carrousel to slide number eight. Reactions which yield heat are called exothermic reactions while those which absorb heat are known as endothermic reactions.

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O + (-57.8\ \text{Kcal})$

ΔH_f is negative

f -- formation

$-\Delta H_f$: heat is given off

: exothermic reaction

$+\Delta H_f$: heat is absorbed

: endothermic reaction

SLIDE #8

One would expect all reactions which yield heat to occur spontaneously. After all, these reactions do occur if some energy is supplied initially. For example, hydrogen explodes if it is ignited, paper burns if a burning match touches it, and propane burns if it is ignited. All these reactions yield energy but why don't they just occur even if energy or heat is not added?

Look at slide number nine. Using the figures from slide number five, methane is at some energy level: namely, -17.9 Kcal/mol. Its combustion products are at -209.6. The difference of 191.7 Kcal should be available.

See Page 256B - Following

SLIDE #9

BAL EQN.: $\underline{1}C_3H_8 + \underline{5}O_2 \longrightarrow \underline{3}CO_2 + \underline{4}H_2O$

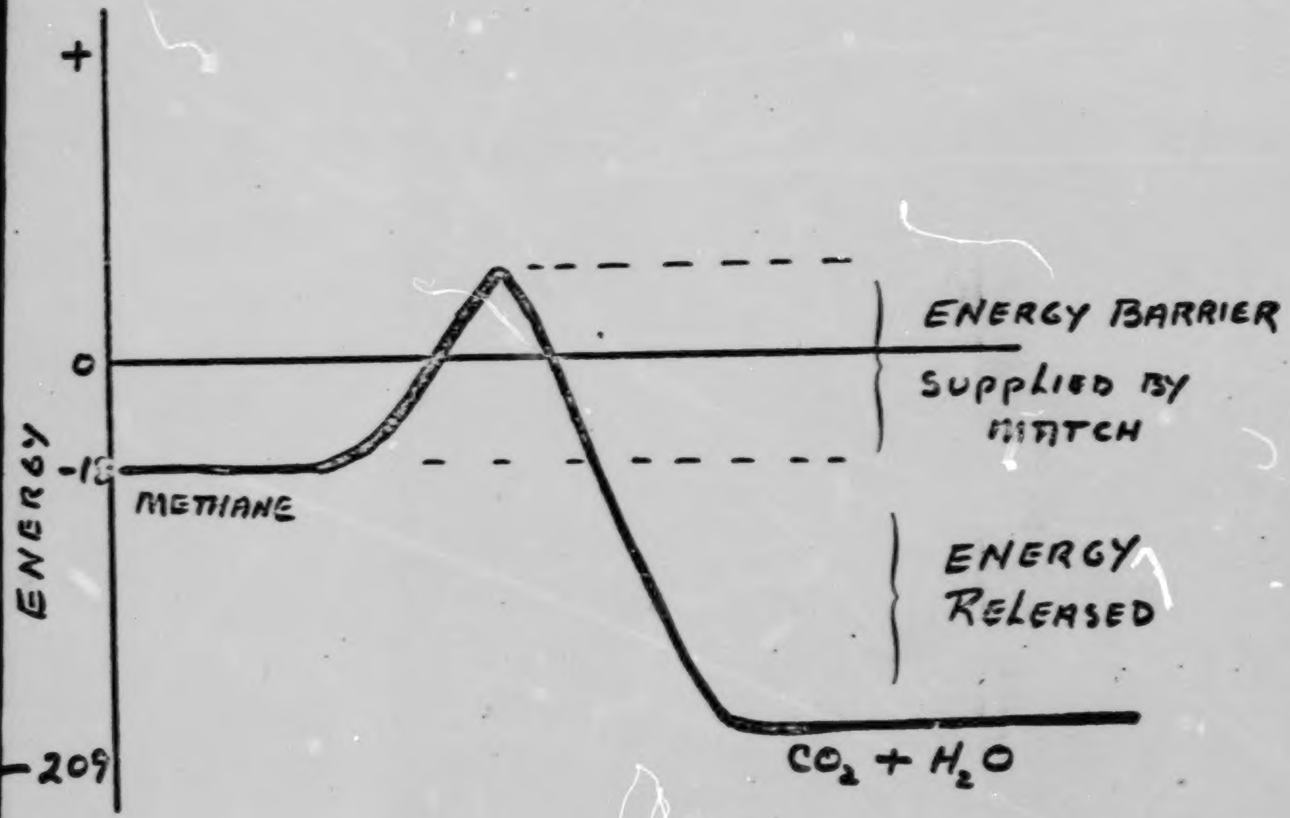
HEAT IN BAL EQN.: $\underbrace{1(-24.8) + 5(0)}_{H_R = -24.8} \longrightarrow \underbrace{3(-94) + 4(-57.8)}_{H_P = -513.2}$

ENTHALPY OF REACTION: $\Delta H = H_P - H_R = -513.2 - (-24.8)$
$= -488.4$ (for $\underline{\text{one}}$ mol C_3H_8)

MOLS PROPANE: $n = \frac{\text{act wt}}{\text{mol wt}} = \frac{22}{44} = \frac{1}{2}$ mols

HEAT PER 22g IS THEREFORE: $\frac{1}{2}(\Delta H/_{\text{mol}}) = -244.2$ Kcal/min

SLIDE #7


+
0
-18
-209
ENERGY
METHANE
ENERGY BARRIER
SUPPLIED BY
MATCH
ENERGY
RELEASED
$CO_2 + H_2O$

The exothermic reactions that do not go spontaneously contain an energy barrier which we call activation energy. Reactions without an energy barrier have long since gone. The match may supply the activation energy for paper or methane. Once the reaction starts its own exothermic heat keeps it going or sustains it (called sustained oxidation).

Energy barriers can be lowered by use of catalysts. A catalyst is a substance which is not used or changed in a reaction but is required to make the reaction occur or go. Enzymes are catalysts. Platinum is often used this way.

Advance to slide number ten. Catalysts lower the amount of energy required to activate a reaction. The catalyst may lower the energy barrier by forming intermediate compounds to whose formation the energy barriers may be lower.

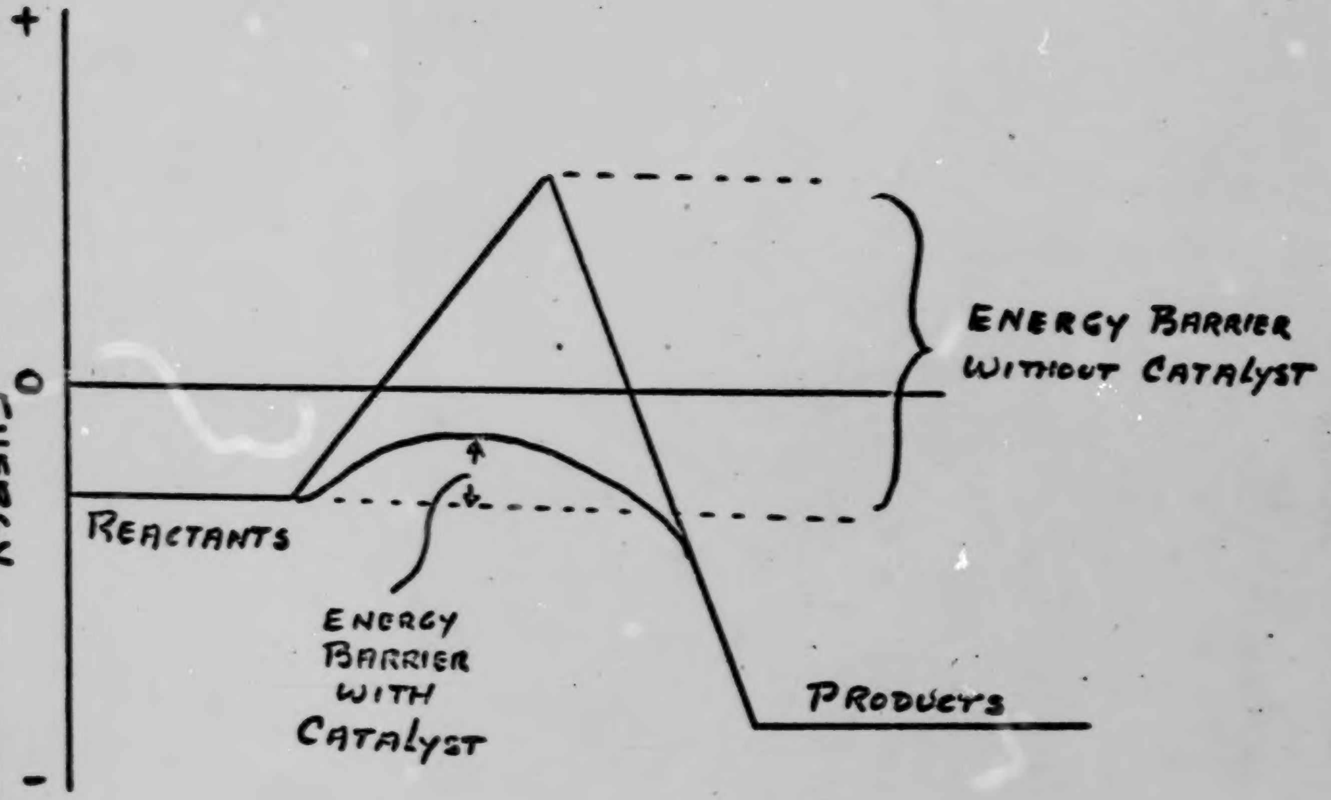
See Page 257A - Following

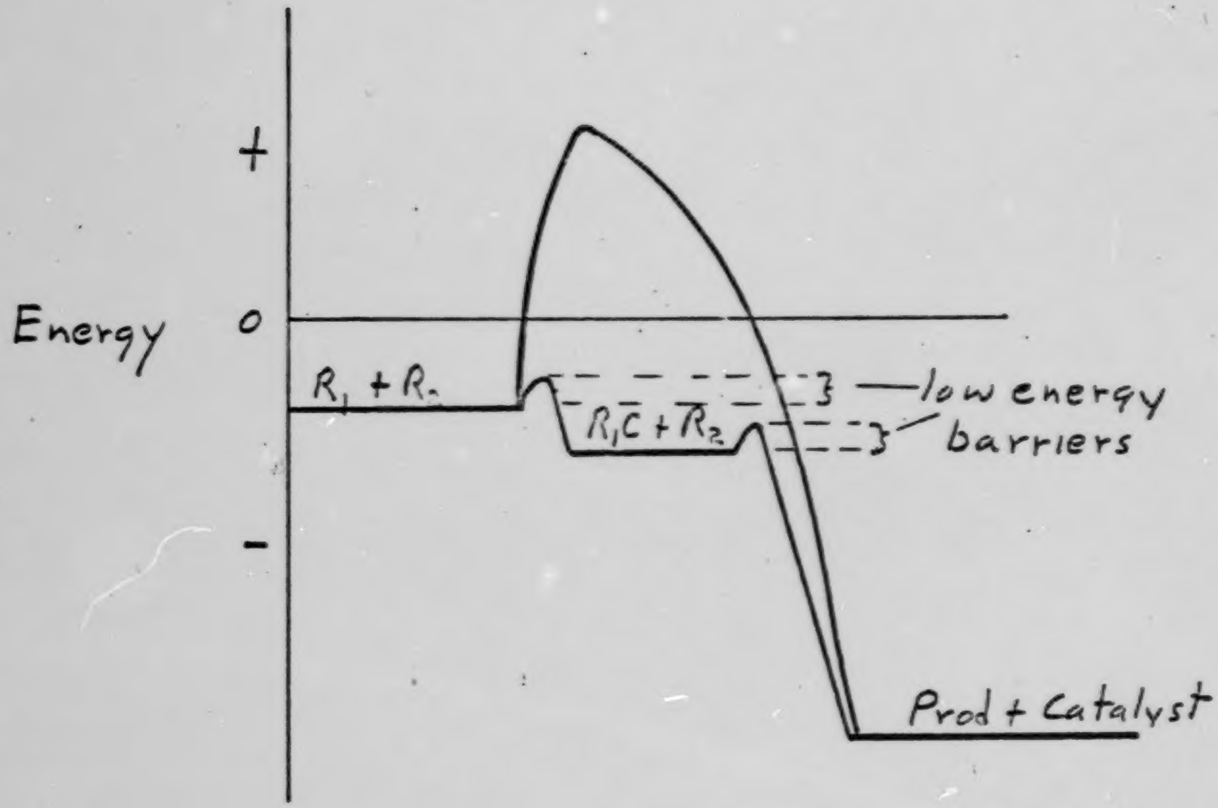
SLIDE #10

Look at slide number eleven. A process in which a catalyst has been added is illustrated in slide number eleven. Some reactant R, may complex with a catalyst to form product R.C.

See Page 257B - Following

SLIDE #11


+
0
ENERGY
-
ENERGY BARRIER WITHOUT CATALYST
REACTANTS
ENERGY BARRIER WITH CATALYST
PRODUCTS


Energy
+
0
-
$R_1 + R_2$
$R_1C + R_2$
low energy
barriers
Prod + Catalyst

SLIDE #11

This reaction has a low energy barrier. R.D. then reacts with R_2 forming the product P and releasing the catalyst. Most of the reactions in your body use this mechanisn for completing reactions.

Now advance to slide number twelve. As a result of studying this section, you should recognize the terminology listed there and be able to do problems involving calculation of heats of reaction. In addition, you should be able to interpret energy diagrams and explain catalysis.

HEAT OF REACTION
EXOTHERMIC
ENDOTHERMIC
ENERGY BARRIER
ACTIVATION ENERGY
CATALYST

Be able to:--CALCULATE HEATS OF REACTION
--INTERPRET ENERGY DIAGRAMS
--EXPLAIN CATALYSIS

SLIDE #12

In the next section we will study reaction rates and equilibrium, but first let us consider systems.

Look at slide number thirteen. A system is a collection of things which, together with their relationships, form a unitary whole.

CHARACTERISTICS OF SYSTEMS

Closed Systems
(1) isolation
(2) equilibrium
(3) maximum entropy

Open Systems
(1) exchange with universe
(2) steady state
(3) self regulation
(4) feedback of information
(5) interplay of subsystems
(6) progressive segregation - specialization of subsystems

SLIDE #13

There are two basic types of systems. One is known as an open system and the other a closed system. Closed systems are characterized by isolation, equilibrium and maximum entropy.

Open systems are much more complex. They have exchange with the universe.

They tend to maintain a steady state. They tend to always produce the same kind of a product. They are self-regulating so they can adjust to the universe. They have feedback of information and interplay of subsystems.

Your body is an example of an open system. It has exchange with the universe. An example of this interchange is the ingesting of food and the use of energy provided by the food. The body must maintain a steady state with regard to temperature, water content, blood sugar levels and so on. It has feedback loops so that it is self-regulating. For example, if blood sugar drops, the liver releases some. There is also a great deal of interplay among the subsystems such as the muscles, various organs, the circulatory subsystem, and the brain.

Social systems are open systems.

Open systems are extremely complex and hard to study and control. Not a great deal of scientific progress has been made with these.

Closed systems, on the other hand, are relatively simple. They can be isolated and the variables in them controlled one by one. Most physical and chemical systems are closed and therefore their parameters can be isolated and studied. The problems become those of measurement. This is why man has made so much more progress in science and engineering than he has in the social, psychological and even medical areas.

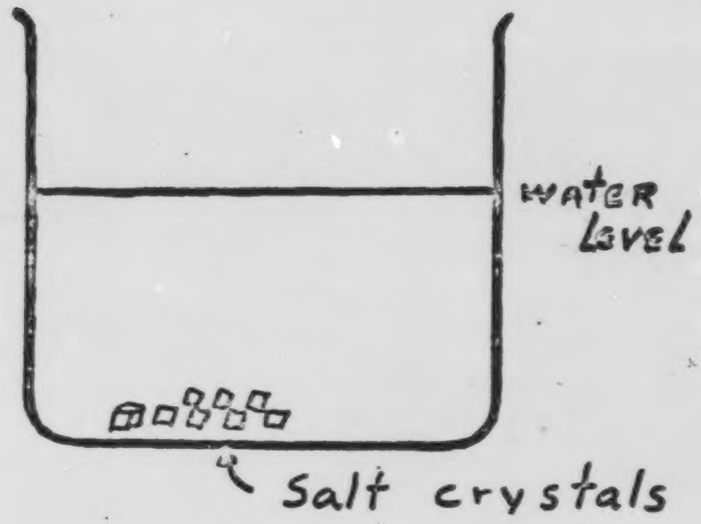
What was the point of this discourse? Science, chemistry particularly, is not something different and all by itself, but rather can be thought of as a study of something larger which we call Systems.

In the study of chemistry, the characteristics we talk about are the characteristics of closed systems, even though we do not usually think of them that way.

See Page 260A - Following

SLIDE #14

Look at slide number fourteen. Consider a system comprised of a beaker of water that has just had a lot of salt dumped into it, a little more than can dissolve. The system is isolated, the first requirement of a closed system. If no more salt is added and none is removed, and the


water level
Salt crystals

Entropy, S, will increase: highly ordered cubic structure breaks up

Equilibrium will be reached

$$NaCl_{(solid)} \underset{recryst}{\overset{solution}{\rightleftarrows}} Na^+ + Cl^-$$

rate of solution = rate of recrystallization

SLIDE #14

temperature and volume held constant, what will happen?

A second characteristic of closed systems is that they tend toward maximum randomness or entropy. Salt crystals are highly organized. The tendency should be toward greater disorganization. As the crystals dissolve greater disorganization, or entropy, will be achieved. The entropy, symbol s, can be measured but we will not do it in this course. It is only necessary for you to realize that there is a tendency toward greater entropy and that any process which tends toward disorder is favored.

The third characteristic of closed systems is a tendency toward equilibrium. At equilibrium no change is apparent, but the situation is not static. As more and more salt crystals dissolve, the chances of their composite parts running into each other and reforming crystals increases. After a while crystals dissolve at the same rate as they reform and equilibrium is reached.

Equilibrium is a dynamic state in a closed system in which opposing reactions or processes progress at the same rate.

SLIDE #15

Advance your carrousel to slide number fifteen.

Equilibrium is a dynamic state in which opposing reactions or processes progress at identical rates.

The rates of reaction are dependent on the concentrations of reactants. The greater the amount of reactants in a given volume the greater the reaction rate. In fact, the reaction rate is directly dependent on concentration, thus doubling concentration of one of two reactants doubles the reaction rate, tripling the concentration triples it, and so on.

Look at slide number sixteen. The rate of reaction is directly proportional to the concentration of each of the reacting substances. This statement is called the Law of Mass Action. If the reaction is that substance A and substance B react to form product C and product D the rate of the forward reaction can be expressed as the concentration of A times the concentration of B. A constant K, is needed to account for the particular materials since some materials, by nature, react faster than others.

LAW OF MASS ACTION: The rate of reaction is directly proportional to the concentration of each of the reacting substances.

SYMBOL FOR CONCENTRATION: [ ]

Generalized Reaction:

$$\nearrow {}_{A}A + {}_{B}B \;---\; {}_{C}C + {}_{D}D$$

coefficient

FORWARD REACTION RATE: $K_1 [A]^A [B]^B$.

REVERSE REACTION RATE: $K_2 [C]^C [D]^D$

SLIDE #16

The reverse reaction rate can be expressed in a similar fashion. The rate is the concentration of C times the concentration of D. Another constant, K_2, is required to account for the nature of the C + D reaction.

Now, with a little mathematical manipulation something useful can be developed.

Look at slide number seventeen. At equilibrium the rate forward = rate reverse. But the rate forward is K_1 AB and the rate reverse is K_2 CD. Dividing by K_2 and AB we have the ratio of constants equal to the ratio of concentrations. A ratio of constants must be constant, call it K. Then K = the product of the concentrations of the products divided by the products of the concentrations of the reactants.

See Page 263A - Following

SLIDE #17

This constant has been worked out for thousands of reactions and can be found in chemical handbooks such as Lange's Handbook of Chemistry. It is called the equilibrium constant.

See Page 263B - Following

SLIDE #18

Advance to slide number eighteen. Let's try a problem to see how it is used. Calcite is calcium carbonate ($CaCO_3$). What will be the concentration of calcium ion in water (H_2O)

AT EQUILIBRIUM

FORWARD RATE = REVERSE RATE

$$K_1[A]^a[B]^b = K_2[C]^c[D]^d$$

$$\frac{K_1}{K_2} = \frac{[C]^c[D]^D}{[A]^A[B]^B}$$

$$\frac{K_1}{K_2} = K$$

$$K = \frac{[\text{1}^{\text{ST}}\text{ PRODUCT}]^{\text{COEF.}}[\text{2}^{\text{ND}}\text{ PRODUCT}]^{\text{COEF}}[\text{3}^{\text{RD}}\ldots}{[\text{1}^{\text{ST}}\text{ REACTANT}]^{\text{COEF}}\ldots}$$

SLIDE #17

1. $CaCO_3 \rightleftharpoons Ca^{++} + CO_3^{=}$
calcite

2. $K_i = 1.0 \times 10^{-8}$

3 But: $K_i = \dfrac{[Ca^{++}]^1 [CO_3^{=}]^1}{[CaCO_3]^1}$

4. $\dfrac{[Ca^{++}][CO_3^{=}]}{[CaCO_3]} = 1 \times 10^{-8}$

5. $[Ca^{++}] = [CO_3^{=}] = X$

$[CaCO_3] = 1$

6 Then $\dfrac{X(X)}{1} = 1 \times 10^{-8}$

$X^2 = 1 \times 10^{-8}$

$X = 1 \times 10^{-4}$

SLIDE #18

that is in contact with calcite rock for a long time?

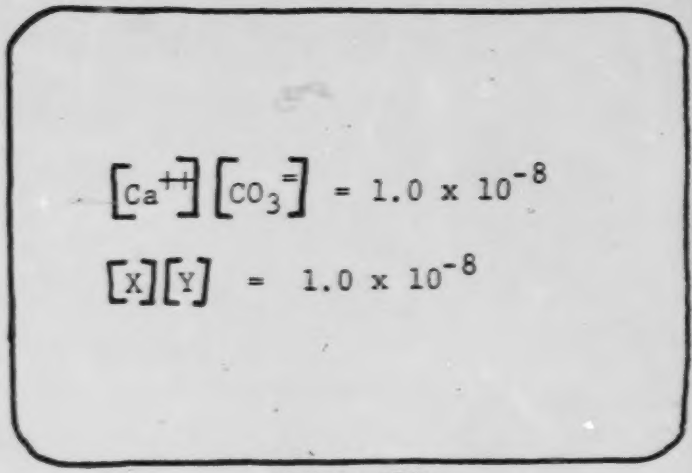
Calcium carbonate ionizes as illustrated in the equation. The equilibrium constant, which is now an ionization equilibrium constant, is 1.0×10^{-8}. But the ionization equilibrium constant is equal to the product of the concentrations of the products divided by the product of the concentrations of the reactants; therefore, equation 4. The concentration of the calcite is far in excess of what will dissolve so its concentration is considered to be unity, that is, have a value of 1.0. The concentration of the Ca^{++} and $CO_3^{=}$ must be the same since one of each is formed every time a calcite molecule dissolves.

Now, let X equal the Ca^{++} concentration as in equation 5. Following through we see that the calcium ion concentration at equilibrium is 1×10^{-4} mols/liter.

This information can be used to calculate the dosages in high pressure boiler water treatment which is Module E4. Generally, it is used in this way.

The calcium ion concentration is controlled by adding carbonate to whatever level is required.

Advance your carrousel to slide number nineteen. The equation shown in slide number nineteen is satisfied in this manner.

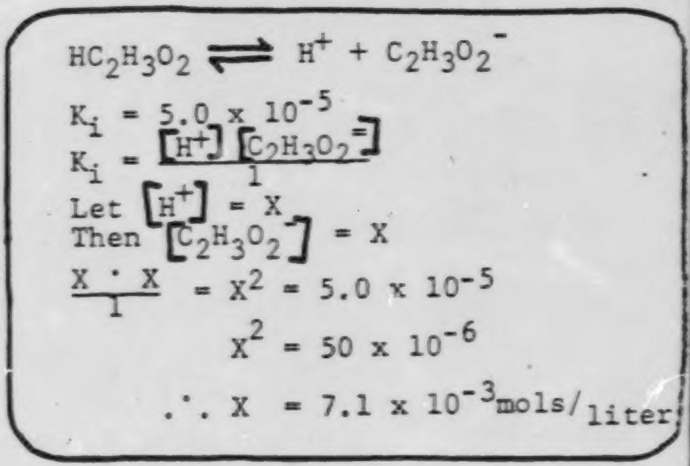


$$[Ca^{++}][CO_3^{=}] = 1.0 \times 10^{-8}$$

$$[X][Y] = 1.0 \times 10^{-8}$$

SLIDE #19

Look at slide number twenty.



$$HC_2H_3O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$$

$$K_i = 5.0 \times 10^{-5}$$

$$K_i = \frac{[H^+][C_2H_3O_2^{=}]}{1}$$

$$\text{Let } [H^+] = X$$

$$\text{Then } [C_2H_3O_2^-] = X$$

$$\frac{X \cdot X}{1} = X^2 = 5.0 \times 10^{-5}$$

$$X^2 = 50 \times 10^{-6}$$

$$\therefore X = 7.1 \times 10^{-3} \text{mols/}_{\text{liter}}$$

SLIDE #20

Now you try a problem like this. Acetic acid (vinegar) ionizes to an extent such that its ionization constant is 5.0×10^{-5}. If one mole of acetic acid is added to a liter of water, what will be the hydrogen ion (H^+) concentration? Slide number eighteen will be of great help to you in your attempt to solve this problem. The problem you are now attempting to solve has been worked out for you on slide number twenty-one, but give it a good try on your own first.

From problem #23 we have an H^+ ion concentration of 2×10^{-2} moles per liter. The log of 2 is +.3010 and the log of 10^{-2} is -2. Their sum is -1.699 or -1.7. The negative log is +1.7 but the negative log is the pH. Therefore, the pH of the solution is 1.7.

We often work with acids. Many times concentrations occur which are of the size obtained in the problem you just worked out. These numbers are not handy to work with and make comparing acid strengths difficult. Another system for naming acid strengths has been devised.

Advance to slide number twenty-one. Acids are usually dissolved in water. Water also ionizes and has an equilibrium constant that must be maintained. Therefore, if the hydrogen ion concentration goes up, the OH concentration must go down proportionately, if the H^+ concentration doubles, OH must be 1/2 and so on.

Now look at slide number twenty-two.

Advance to slide number twenty-three. Let us assume that we have a .02 molar HCl solution and that all the HCl ionizes. Then H^+ concentration = 2.0×10^{-2}. The OH concentration = 5×10^{-11} so that the ionization constant of 10^{-14} for water can be maintained.

To handle these numbers more easily, logarithms of the numbers

$$\mathrm{HOH} \rightleftharpoons \mathrm{H}^+ + \mathrm{OH}^-$$
$$K_i = 1.0 \times 10^{-14}$$
$$[\mathrm{H}^+][\mathrm{OH}^-] = 1.0 \times 10^{-14}$$
$$\text{Let } [\mathrm{H}^+] = X$$
$$\text{Then } X^2 = 1.0 \times 10^{-14}$$
$$X = 1.0 \times 10^{-7}$$

SLIDE #21

$$[\mathrm{H}^+][\mathrm{OH}] = 1.0 \times 10^{-14}$$
$$(1.0\times10^{-7})(1.0\times10^{-7}) = 1.0 \times 10^{-14}$$
$$(^1/2 \times 10^{-7})(2 \times 10^{-7}) = 1.0 \times 10^{-14}$$
$$(^1/_5 \times 10^{-7})(5 \times 10^{-7}) = 1.0 \times 10^{-14}$$
$$(^1/_N \times 10^{-7})(N \times 10^{-7}) = 1.0 \times 10^{-14}$$
$$(1.0 \times 10^{-3})(1.0 \times 10^{-11}) = 1.0\times10^{-14}$$
$$1.0 \times 10^{-14}$$

$$[\mathrm{H}^+][\mathrm{OH}^-] = 1.0 \times 10^{-14}$$
$$(2 \times 10^{-2})[\mathrm{OH}^-] = 1.0 \times 10^{-14}$$
$$[\mathrm{OH}^-] = 0.5 \times 10^{-12}$$
$$= 5 \times 10^{-13} \text{ mols/liter}$$

SLIDE #23

are used, rather than the numbers themselves. The negative logarithm of the hydrogen ion concentration is called pH.

Look at slide number twenty-four.

Now advance to slide number twenty-five.

Let us consider the problem which was started on slide number twenty-three.

If the logs throw you, go to the remedial math skills module, R-5. If not, continue.

Look at slide number twenty-six. We can now see why pure water has a pH of 7.000. Since the ionization constant of water is 10^{-14}, the H^+ concentration is 10^{-7}. The log of 10^{-7} = -7. The negative log then is +7 which is the pH.

Now return to slide 20 where you found the concentration of H^+ ion in an acetic acid solution. Take the H^+ concentration answer and find the pH. The problem is worked out on slide number twenty-seven, but try it yourself first.

Advance to slide number twenty-seven.

pH is the negative logarithm of the hydrogen ion concentration.

pOH is the negative logarithm of the hydroxide ion concentration.

SLIDE #24

From Slide #23: $[H^+] = 2\text{x}10^{-2}\,\frac{\text{mols}}{\text{l}}$

$$\begin{aligned}\log 10^{-2} &= -2.0000\\ \log 2 &= \underline{+\ .3010}\\ \text{sum} &= -1.6990\end{aligned}$$

negative log = -(-1.6990) = pH

pH = +1.699 or -1.7

SLIDE #25

$[H^+][OH^-] = 1.0 \text{ x } 10^{-14}$

since: $[H^+] = [OH^-]$

$$\begin{aligned}[H^+] &= \sqrt{1.0 \text{ x } 10^{-14}}\\ &= 1.0 \text{ x } 10^{-7}\end{aligned}$$

But: $\log 1.0 \text{ x } 10^{-7} = 17$

and: $\text{pH} = -\log [H^+] = -\log 10^{-7}$

$\text{pH} = -(-7) = +7$

SLIDE #26

Let's try one backwards. What is the hydrogen ion concentration in moles per liter of boiler water with a pH of 8.5? The problem has been solved on slide number twenty-eight, but see if you can solve it before viewing slide twenty-eight.

Now advance to slide number twenty-eight.

Advance to slide number twenty-nine.

As a result of studying this section, you should be able to define the terms and relationships listed on slide number twenty-nine. Further, you should be able to work problems related to these terms and relationships.

$[H^+] = 7.1 \times 10^{-3}$

$\log 10^{-3} = -3.0000$

$\log 7.1 = \underline{+\ .8513}$

2.1487

$\therefore\ pH = +2.1$

SLIDE #27

GIVEN: pH = 8.5

We need to find antilog -8.5

CRITICAL STEP: $-8.5 = -9 + \underline{\underline{0.5}}$

Table of Mantissas is for + values only

Antilog $-9 = 10^{-9}$

Antilog $0.5 = 3.162$

$\therefore\ [H^+] = 3.16 \times 10^{-9}$ mols/liter

SLIDE #28

System
Open System - Closed
Relationship of Systems to Chemistry
Equilibrium
Entropy
Relationship of Equilibrium and Entropy to What Happens in a Closed System
Law of Mass Action
Equilibrium Constant
pH
Calculations: Problems Involving Equilibrium and pH Problems

SLIDE #29

MODULE B-1 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the MODULE B-1 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE B-1 as well as to the completion of the problem set. Those pages are: 49, 53, 109-113, 116, 122, 132-134, 265, 268-278, 295, 298.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown.

(Read Across)

Page	Problems
117	1, 2, 10
300	6

MODULE B-1 PROBLEM SET SOLUTIONS

Page	Problem	
117	(1)	Pure water has the higher surface tension. The addition of a substance to pure water lowers the surface tension of the water.
117	(2)	Water has the same vapor pressure at 80°C as chloraform has at 40°C.
117	(10)	The molecules with higher kinetic energy evaporate leaving those of lower energy (cooler) behind.
300	(6)	$2C_4H_{10} + 13O_2$ ---- $8CO_2 + 10H_2O$

Name ______________________

MODULE B1 - 1 EXAMINATION

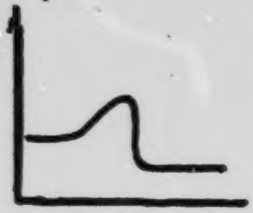
1. Given the following heats of formation:

H_2O (gas)	-57.8
CH_4	-17.9
CO_2	-94.1

How much heat will be given off when I burn 4,000 liters of methane (CH_4)?

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O$$

2. If the following is a diagram of the energy in a chemical reaction, what would the diagram look like if I used a catylist?



3. Write the expression for the equilibrium constant of the following reaction:

$$CO + H_2O \rightleftarrows CO_2 + H_2$$

k = ______________________

4. If I add water in the above reaction, which way will the reaction move? Explain your answer.

P. 272

MODULE B1 - 1 EXAMINATION SOLUTION SET

1. 1 mole of CH_4 = 22.4 liters

$$\text{moles of } CH_4 = \frac{4000 \text{ liters}}{22.4 \text{ liters}} = 178.5 \text{ moles}$$

The balanced equation is $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

When compounds are involved in a reaction, the heats of formation of the reacting compounds must be subtracted from the heats of formation of the products.

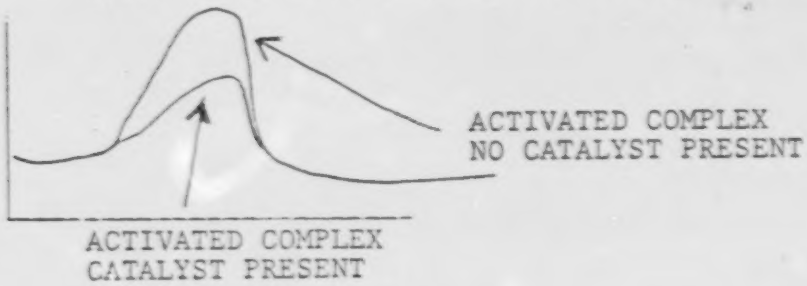
CH_4	+	$2O_2$	$\longrightarrow$	CO_2	+	$2H_2O$
-17.9kcal/mole		no heat of formation		-94kcal/mole	+	2(-57.8kcal/mole)
	-17.9kcal/mole			-94kcal/mole	+	-115.6kcal/mole
					-209.6kcal/mole	

$$\begin{array}{r} 209.6 \\ \underline{17.9} \\ 191.7 \end{array}\text{kcal/mole}$$

This means that for each mole of CH_4 which is burned, 191.7kcal of heat is produced. It follows that burning 178.5 moles of CH_4 will produce:

178.5 moles x 191.7kcal/mole = 34,218.45kcal.

2.



3.

$$K_{forward} = \frac{(CO_2)\ (H_2)}{(CO)\ (H_2O)} \qquad K_{reverse} = \frac{(CO)\ (H_2O)}{(CO_2)\ (H_2)}$$

4. If water is added to the reaction, the reaction should shift to the right, that is, in a direction that will maintain the equilibrium constant.

Module B1
P. 273

Name ____________________

MODULE B1 - 2 EXAMINATION

1. What are the three properties of a closed system?

2. What is the function of a catalyst in a reaction?

3. What do the square brackets mean when used around a chemical formula?

4. What does the law of mass action tell us about the rate of a reaction?

5. In the following reaction, what is the expression for the equilibrium constant?

$$A + B \rightleftharpoons C + D$$

k = ________________

6. In the above reaction, if B was water, and I removed some of it, which way would the reaction move?

7. What would happen to the concentration of C and D? Prove it.

MODULE B1 - 2 EXAMINATION SOLUTION SET

1. Closed systems are characterized by:
   a. isolation
   b. equilibrium
   c. maximum enthropy
2. A catalyst changes the rate of a chemical reaction without entering into the chemical reaction. It does this by lowering the amount of activation energy which is required before a reaction can begin.
3. The symbol [ ] stands for concentration.
4. The Law of Mass Action states that the rate of reaction is directly proportional to the concentration of each of the reacting substances.
5. $K = \frac{(C)\ (D)}{(A)\ (B)}$
6. If some water were removed, the reaction would go in the direction of A + B so that the equilibrium constant would be maintained.
7. The concentrations of C and D would increase. The proof of this action is that the value of K is maintained.

Name ______________________

MODULE B1 - 3 EXAMINATION

1. Construct an explanation of the sequence of events as a solid is heated in terms of energy in temperature changes and phase changes. Assume the kinetic-molecular theory, use a diagram if you wish but include an explanation:

2. Define exothermic and endothermic and explain the relationship between these two terms.

3. What is the role of a catalyst?

4. Give the characteristics of an open system and a closed system. Explain what is meant by the term system when speaking of open and closed systems.

Continued . . .

EXAMINATION
Continued
P. 276

5. What is an equilibrium constant? Explain by giving an example and how K_i is derived.

6. Hydrocyanic acid, HCN, ionizes as follows:

$$HCN + H_2O \longrightarrow H_3O^+ + CN^-$$

a. Write the expression for the ionization constant of HCN.

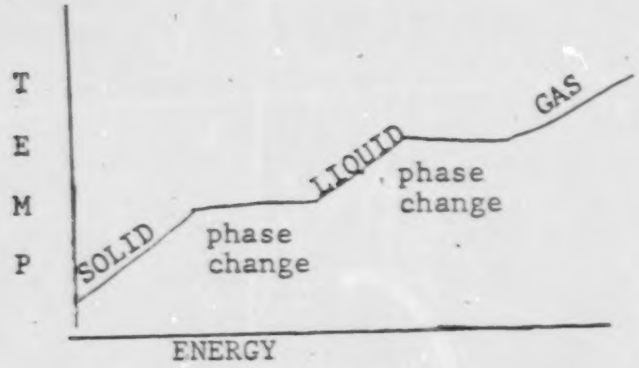
b. The value of K_{ion}' for HCN is 7.2×10^{-10} at 25°C. Is HCN a strong or weak acid?

c. What is the concentration of CN^- in a solution containing 0.25 mole/liter of HCN?

d. What is the pH of this solution?

MODULE B1 - 3 EXAMINATION SOLUTION SET

1.



A material takes on energy as it moves between phase changes. A phase change occurs once the material has accumulated sufficient energy; however, the change in phase is not instantaneous. Therefore, although energy continues to be added during a phase change the temperature does not increase.

2. An exothermic reaction is one in which heat is given off while an endothermic reaction requires the addition of heat in order to occur.

3. A catalyst changes the rate of a chemical reaction without entering into the chemical reaction. It does this by lowering the amount of activation energy which is required before a reaction can begin.

4. Closed systems are characterized by isolation, equilibrium and maximum enthropy. A system is a collection of things or parts which when put together form a unitary whole.

5. An equilibrium constant is a numerical constant characteristic of a given reaction at equilibrium at a given temperature. It is equal to the specific rate constant of the forward reaction divided by the specific rate constant of the reverse reaction.

6. a. $K_i = \frac{(H_3O^+)\ (CN^-)}{(HCNaq)}$

   b. Weak acid

   c. Let x equal the H_3O^+ and CN^- ion concentrations at equilibrium. The concentration undissociated HCN(aq), equals the initial concentration minus the number of dissociated moles per liter. Since the number dissociated must equal x, the concentration of HCN at equilibrium is 0.25-x. Also, since x is small compared to 0.25 it can be neglected to give (HCN(aq)) equal to 0.25. By substitution

continued . . .

6. c. continued

$$\frac{xx}{0.25} = 7.2 \times 10^{-10}$$

$$x^2 = 0.25 \times 7.2 \times 10^{-10} = 1.8 \times 10^{-10} = 1.3 \times 10^{-5}$$

Therefore, the concentration of CN^- ions in a 0.25M solution is 1.3×10^{-5} moles/liter.

d. $[H^+]$ concentration $= 1.3 \times 10^{-5}$

$$\log 10^{-2} = -5.0000$$

$$\log 1.3 = \underline{+\ .1139}$$

$$-4.8861$$

$$pH = -(-4.88)$$

$$pH = 4.9$$

Name ______________________

MODULE B1 - 4 EXAMINATION

1. How is it possible to determine the kinetic energy of the molecules in an object?

2. The heat of formation of sodium oxide is -99.4 Kcal/mole. Based upon this information, what can be said concerning the stability of the oxide?

3. Draw two diagrams of a reaction, one in which only the reactants are present and one in which the reactants plus a catalyst are present.

4. What would you expect to happen to reactions in a closed system. Would they move toward disequilibrium and maximum entropy or toward equilibrium and order and why?

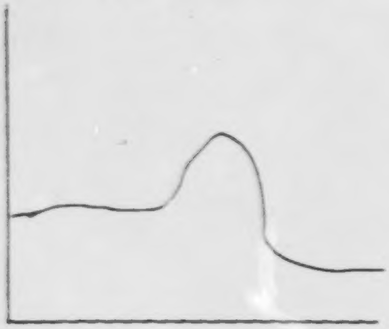
5. What happens to water while ice is melting and how can you account for this observation?

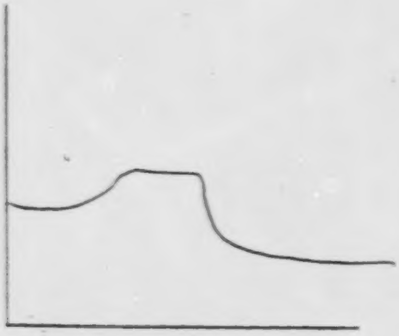
MODULE B1 - 4 EXAMINATION SOLUTION SET

1. By taking the temperature of the object.

2. The compound is at a lower energy state than were the reactants. Since the reaction is exothermix its stability is greater than the individual reactants.

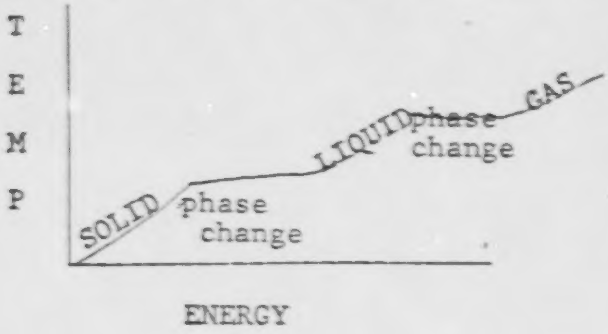
3.





4. Generally, in a closed system a reaction would move toward equilibrium. It would move toward increased (macimum) entropy if there were more products (molecules in the product) than in the reactions. Also, generally speaking, all chemical reactions increase the maximum entropy of the universe.

5.



Name ______________________

MODULE B1 - 5 EXAMINATION

1. Define the following terms:

   a. closed system

   b. catalyst

   c. mass action

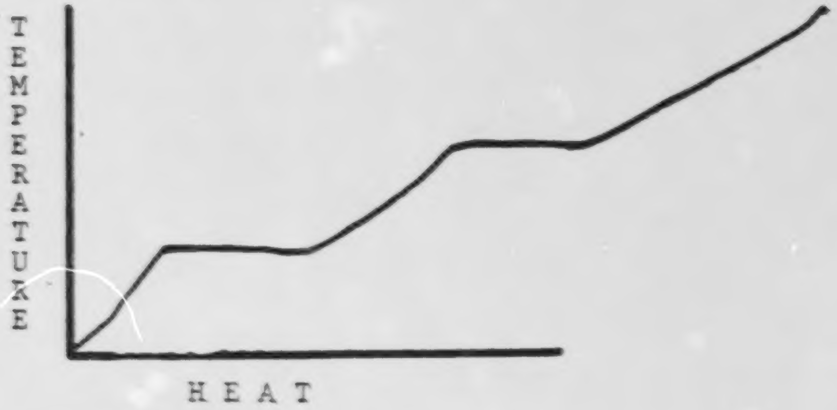
   d. equilibrium constant

   e. heat of formation

   f. exothermic reaction

   g. endothermic reaction

2. The following diagram is related to some substance. Discuss in detail its meaning.



MODULE B1 - 5 EXAMINATION SOLUTION SET

1. a. Closed systems are characterized by isolation, equilibrium and maximum enthropy.

   b. A catalyst changes the rate of a chemical reaction without entering into the chemical reaction. It does this by lowering the amount of activation energy which is required before a reaction can begin.

   c. The Law of Mass Action states that the rate of reaction is directly proportional to the concentration of each of the reacting substances.

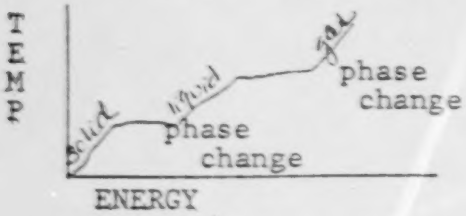
   d. An equilibrium constant is a numerical constant characteristic of a given reaction at equilibrium at a given temperature. It is equal to the specific rate constant of the forward reaction divided by the specific rate constant of the reverse reaction.

   e. The heat of formation is either the heat taken on or the heat given off when a chemical reaction occurs.

   f. An exothermic reaction is one in which heat is given off..

   g. An endothermic reaction requires the addition of heat in order to occur.

2. A material takes on energy as it moves between phase changes. A phase change occurs once the material has accumulated sufficient energy; however, the change in phase is not instantaneous. Therefore, although energy continues to be added during a phase change the temperature does not increase.



Name ____________________

MODULE B1 - 6 EXAMINATION

1. What would you anticipate to happen to a molecule of a substance as the substance begins to change state?

2. What would you expect to happen to the density of a substance as the substance changes from a lower to a higher energy state?

3. When you place your hand near an oil burner, you feel a large amount of heat. What is the meaning of your observance?

4. Define the following terms:

   a. open system

   b. closed system

   c. equilibrium constant

5. What could you do to speed up the rate of a chemical reaction?

MODULE B1 - 6 EXAMINATION SOLUTION SET

1. The molecule would continue to gain energy but its temperature would tend not to increase.

2. Generally, the denisty would tend to decrease since the molecules are moving farther apart as one goes from a lower to a higher energy state.

3. The amount of heat is indicative of the energy state of molecules.

4. a. Open systems have exchange with the universe; they tend to maintain a steady state; they have feedback loops so that they are self-regulating; and there is a great deal of interplay among subsystems.

   b. Closed systems are characterized by isolation, equilibrium, and maximum enthropy.

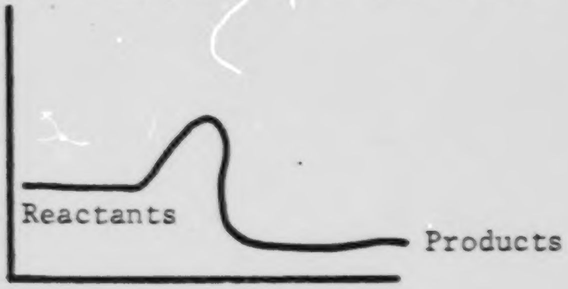
   c. An equilibrium constant is a numerical constant characteristic of a given reaction at equilibrium at a given temperature. It is equal to the specific rate constant of the forward reaction divided by a specific rate constant of the reverse reaction.

   d. A catalyst changes the rate of a chemical reaction without entering into the chemical reaction. It does this by lowering the amount of activation energy which is required before a reaction can begin.

Name ______________________

MODULE B1 - 7 EXAMINATION

1. Discuss the meaning of the diagram presented below:



2. Define the following terms:

   a. sublimation

   b. open system

   c. closed system

   d. catalyst

   e. equilibrium constant

3. What is the effect of heat upon a reaction rate?

4. In the following reaction, what is the expression for the equilibrium constant?

$$X + Y \rightleftharpoons W + Z$$

MODULE B1 - 7 EXAMINATION SOLUTION SET

1. The diagram indicates that the products of a chemical reaction are at alower energy level than the reactants. Further, it indicates that the reactants have not been catalyzed.

2. a. Sublimation is the change directly from a solid to a gas.

   b. Open systems have exchange with the universe; they tend to maintain a steady state; they have feedback loops so that they are self-regulating; and there is a great deal of interplay among subsystems.

   c. Closed systems are characterized by isolation; equilibrium; and maximum enthropy.

   d. A catalyst changes the rate of a chemical reaction without entering into the chemical reaction. It does this by lowering the amount of activation energy which is required before a reaction can begin.

   d. An equilibrium constant is a numerical constant characteristic of a given reaction at equilibrium at a given temperature. It is equal to the specific rate constant of the forward reaction divided by the specific rate constant of the reverse reaction.

3. Heat increases the activities of molecules and therefore increases the probability that they will collide. It follows that heat then increases the rate of reaction.

4.

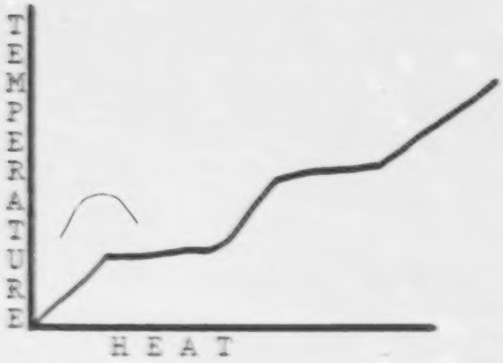
$$K = \frac{[W]\,[Z]}{[X]\,[Y]}$$

Name ______________________

MODULE B1 - B EXAMINATION

1. What is the relationship between the Law of Mass Action and chemical reactions?

2. The diagram presented below is related to some substance. Discuss its meaning:



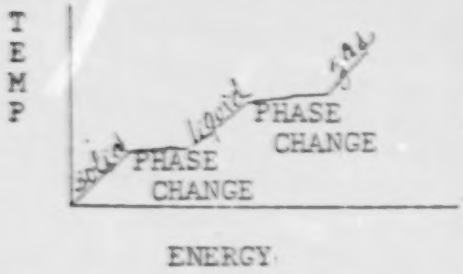
3. What happens to the temperature of your drink as the ice cubes melt?

4. Write an expression for the equilibrium constant of the following reaction:

$$2H_2 + O_2 \rightleftarrows 2H_2O$$

MODULE B1 - 8 EXAMINATION SOLUTION SET

1. The Law of Mass Action states that the rate of reaction is directly proportional to the concentration of each of the reacting substances.

2. 

A material takes on energy as it moves between phase changes. A phase change occurs once the material has accumulated sufficient energy; however, the change in phase is not instantaneous. Therefore, although energy continues to be added during a phase change the temperature does not increase.

3. The temperature remains constant.

4.

$$K = \frac{(H_2O)^2}{(H_2)^2\ (O)_2}$$

Name ______________________________

MODULE B1 - 9 EXAMINATION

1. Define the following terms:

    a. + Kcal/mole

    b. exothermic

    c. endothermic

    d. equilibrium constant

    e. catalyst

    f. open system

    g. closed system

    h. mass action

    i. heat of formation

2. Draw a diagram of what you would expect to happen as a substance is heated from the point where is is a solid to the point where it is a gas.

3. Describe in detail the drawing you have just made.

MODULE B1 - 9 EXAMINATION SOLUTION SET

1. a. + Kcal/mole indicates the amount of heat which must be taken on in order that a reaction will occur.

   b. An exothermic reaction is one in which heat is given off.

   c. An endothermic reaction requires the addition of heat in order to occur.

   d. An equilibrium constant is a numerical constant characteristic of a given reaction at equilibrium at a given temperature. It is equal to the specific rate constant of the forward reaction divided by the specific rate constant of the reverse reaction.

   e. A catalyst changes the rate of a chemical reaction without entering into the chemical reaction. It does this by lowering the amount of activation energy which is required before a reaction can begin.

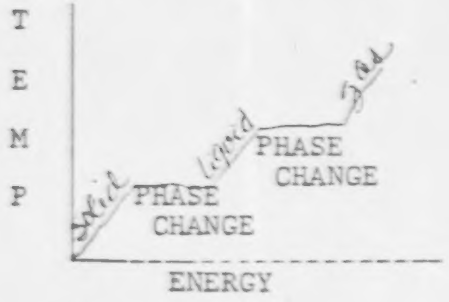
   f. Open systems have exchange with the universe; they tend to maintain a steady state; they have feedback loops so that they are self-regulating; and there is a great deal of interplay among subsystems.

   g. Closed systems are characterized by isolation, equilibrium and maximum enthropy.

   h. The Law of Mass Action states that the rate of reaction is directly proportional to the concentration of each of the reacting substances.

   i. The heat of formation is either the heat taken on or the heat given off when a chemical reaction occurs.

2.



3. A material takes on energy as it moves between phase changes. A phase change occurs once the material has accumulated sufficient energy; however, the change in phase is not instantaneous. Therefore, although energy continues to be added during a phase change the temperature does not increase.

Name ____________________

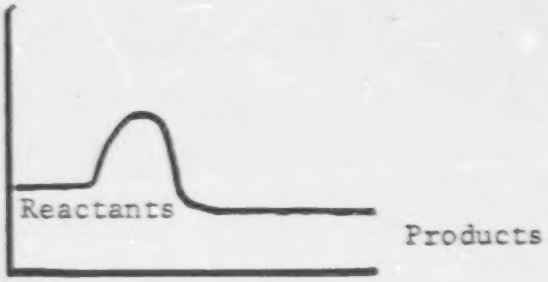
MODULE B1 - 10 EXAMINATION

1. What happens to the kinetic energy of molecules in a substance as the substance changes from a liquid to a solid?

2. What happens to reactions in a closed system?

3. You observe steam to be rising from a block of dry ice. How can you account for your observations?

4. Discuss the following diagram:



5. What does the heat of formation of a substance indicate to you?

6. Define:
    a. Catalyst
    b. Equilibrium constant

MODULE B1 - 10 EXAMINATION SOLUTION SET

1. The amount of kinetic energy remains constant. .

2. Closed systems are characterized by isolation, equilibrium and maximum enthropy.

3. This is a phenomenon known as sublimation. When this occurs, solids change directly from solids to gases without going through the liquid phase.

4. The diagram indicates that the products of a chemical reaction are at a lower energy level than the reactants. Further, it indicates that the reactants have not been catalyzed.

5. The heat of formation is either the heat taken on or the heat given off when a chemical reaction occurs.

6. a. A catalyst changes the rate of a chemical reaction without entering into the chemical reaction. It does this by lowering the amount of activation energy which is required before a reaction can begin.

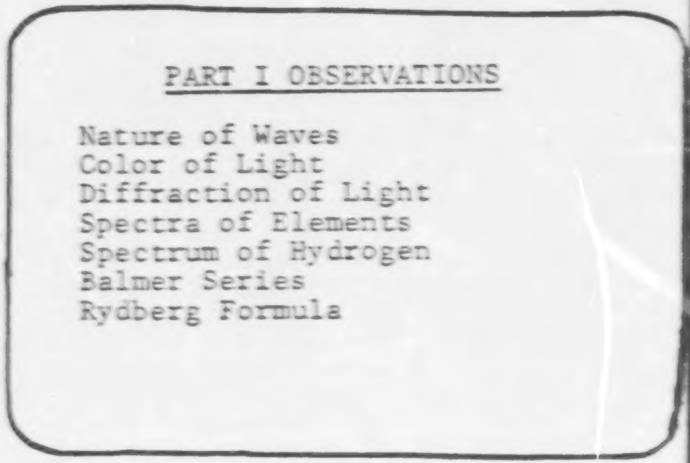
   b. An equilibrium constant is a numerical constant characteristic of a given reaction at equilibrium at a given temperature. It is equal to the specific rate constant of the forward reaction divided by the specific rate constant of the reverse reaction.

ATOMIC STRUCTURE

Module A1, Atomic Structure, is the only module intended to be studied specifically at the A competency level.

As a result of studying this module, your understanding of the theory of chemistry will increase significantly. You will be able to discuss the contributions of Maxwell, Thomson, Balmer, Rydberg, Rutherford, Bohr, Planck, Einstein, Schrodinger and Pauli to our understanding of the atom. Further, you will be able to discuss and illustrate the concepts of wavelength, spectrum, quantum, quantum numbers, electron configurations, hybridization, sigma bonds, pi bonds, and polar molecules.

Now advance your slide carrousel to slide number one. In this unit we will study the electron configuration in the atom and how this configuration is related to the activity of the atom. On slide number one there is a topical outline of the first of the three sections of this



PART I OBSERVATIONS

Nature of Waves
Color of Light
Diffraction of Light
Spectra of Elements
Spectrum of Hydrogen
Balmer Series
Rydberg Formula

SLIDE #1

unit. Each of these topics will be examined in turn, but let's note here that we came to our present understanding of the electron configuration in atoms and, therefore, some chemistry, through our understanding of the properties of light.

Look at slide number two. This slide continues the outline. In this section of the unit we will examine the concept that jarred the minds of the leading physicists of their day. The concept was that energy was quantized, that it came in packets of specific sizes like atoms in matter.

PART II THEORY

Concept of the Quantum
Bohr - Maxwell - Planck - Einstein
Bohr Atom
Wave Nature of Matter
    DeBroglie
    Schrodinger
Four Quantum Numbers
Pauli Exclusion Principle

SLIDE #2

Advance to slide number three. Once we have some understanding of the energy levels of the electrons we can begin to understand why the periodic table has the form it does and how molecules are formed by the interaction of the electrons of several atoms.

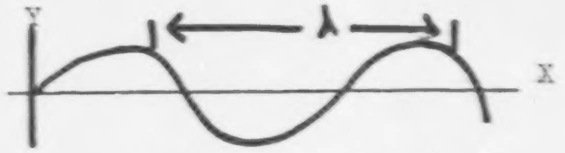
PART III

A. Periodic Table in Terms of Electron Energy Levels

B. Types of Bonding in Terms of Electron Configuration

SLIDE #3

Look at slide number four. You are familiar with the phenomenon of ripples moving out from the point where a stone was dropped into a still pond. If we watch a small cork



Velocity = Frequency x Wavelength

$v = f \times \lambda$

$v = \nu \times \lambda$

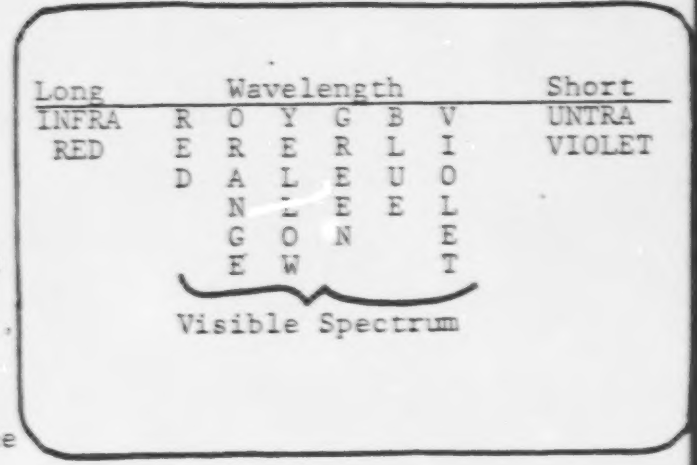
$c = \nu \times \lambda$

Nu   Lambda

SLIDE #4

floating on the surface of the pond we see that it rises and falls as the ripples pass. We can make a graph of either the up-down motion of the cork plotted against time, or of the displacement of the surface of the water plotted against distance along the surface. On the slide, the displacement of the surface water is plotted against distance. The distance from any one point on the wave pattern to the corresponding point on the next wave, where the pattern starts to repeat itself, is called the wavelength. The usual symbol for wavelength is the Greek letter lambda, which looks like an upside down "Y". (λ) Remember, wavelength is a physical distance. The relationship between frequency, wavelength, and velocity of a wave through some medium (water, air, vacuum), is given by the formula: velocity equals frequency times wavelength. ($V = f$ xλ) This is an empirically observable relationship. The symbol for frequency is sometimes a script "f" but most often the Greek letter nu, as shown on the slide. The symbol for velocity is generally the letter "V" except for the velocity of light where the small letter "c" is used. You should be able to write the equation relating the velocity, frequency and wavelength of a wave.

Advance to slide number five. Light is a wave. It is a rapid pulsation of a combined electric and magnetic field in space and is called an electromagnetic wave. Radio waves, radiant heat, and Xrays are also electromagnetic waves. The difference between these different types of electromagnetic radiation is their frequency of vibration. The difference between the different colors of visible light is their frequency of vibration. Since the velocity of light in a vacuum is a constant, the colors of light each have a different wavelength. The actual wavelengths range from 4.0×10^{-5} cm. for violet light to 7.5×10^{-5} cm. for red light. The spread of all the colors, from the longest wavelength to the shortest are named on slide five.



SLIDE #5

Now look at slide number six. On slide six we see the colors as their frequency changes. Remember, red has the longest wavelength. This spread of colors is called a spectrum. Since every wavelength is represented we call it a continuous spectrum.

The slide shows the color spectrum from 4000A - 7800A compared with the colors of light emitted by H, Ca, Fe and Na.

SLIDE #6

Look at slide number seven. A color spectrum can be obtained quite simply. If a beam of white light is projected through a prism onto a screen, a spectrum of colors is obtained. If the light being examined is not pure white light, then all the colors of the continuous spectrum will not be present, but only those colors or those wavelengths, that make up the light of the color being studied.

The slide shows a beam of white light passing through a triangular prism and the color breakdown.

SLIDE #7

Advance to slide number eight. If a gas is put into a tube and a current passed through the gas, the gas will glow. This is what happens in an ordinary neon tube or fluorescent light. If the light which is produced by the gas is passed through a prism and onto a screen, a bright line spectrum is obtained. Using an instrument called a spectrometer, it

See page 297A - Following

SLIDE #8

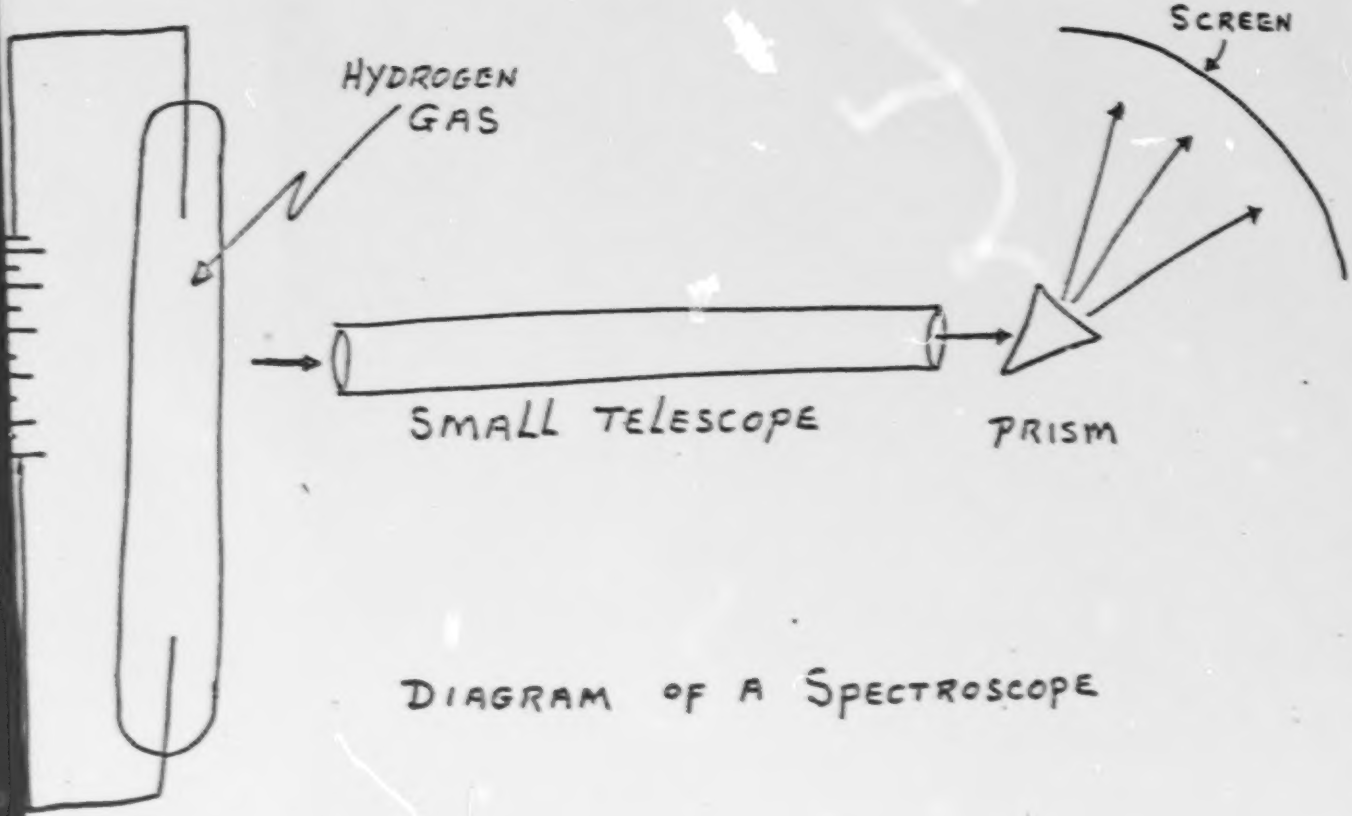

SCREEN
HYDROGEN GAS
SMALL TELESCOPE
PRISM

DIAGRAM OF A SPECTROSCOPE

is possible to measure the frequencies or wavelengths of the light which is given off by the ionized gas. The light given off by the ionized gas is called the spectrum of that gas.

This slide shows the colors of light emitted by Na, H, Ca, Hg, and Ne (between 3800A and 7800A).

SLIDE #9

Look at slide number nine. On slide number nine we see the sets of colors which make up the spectra of sodium, hydrogen, calcium, mercury, and neon. Each element has its own set of lines or spectrum. These optical fingerprints identify the element. The study of these optical fingerprints is called spectroscopy. The individual lines or colors are called spectral lines.

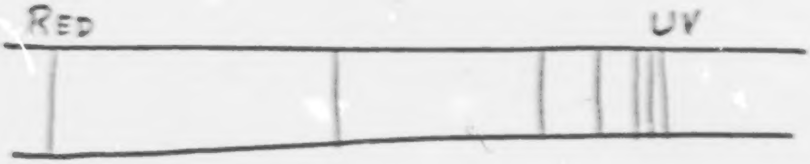
The first spectoscope was invented in 1859 as physicists attempted to make some sense out of the lines produced by glowing gases. In their investigation they questioned why different elements give off lines of different colors and whether there was any relationship between the lines and a given element.

See Page 298A - Following

SLIDE #10

Advance to slide number ten. The visible spectrum of hydrogen gave a series of lines whose wave-

BALMER SERIES 1885
HYDROGEN LINES



$$\lambda = h \frac{m^2}{m^2 - 4}$$

$h = 3645.6$

$m = 1, 2, 3, 4, \cdots$

EMPIRICAL FORMULA

SLIDE #10

lengths were accurately measured. In 1885 a Swiss school teacher was trying to see if there was any relationship between the wavelengths. He discovered the expression which is shown on slide number ten. Lambda is defined as the wavelength of each spectral line. It is given by a constant times the expression m squared over (divided by) m squared minus 4. The formula works only if m takes on integer values such as 1, 2, 3 and so on (m cannot equal 0). Each number gives the wavelength of the next spectral line. This formula is an empirical formula. It is based on observation and predicts what the wavelength of each line should be. It does not tell us WHY each wavelength has that value.

The scientists of that era were curious about why the atoms of hydrogen gave off colors whose wavelengths were so simply related.

Now advance to slide number eleven. Five years after Balmer had made his discovery, another more general formula was derived by Rydberg.

RYDBERG 1890

BALMER SERIES $\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{m^2}\right)$

ANY SERIES $\frac{1}{\lambda} = R_H\left(\frac{1}{m_1^2} - \frac{1}{m_2^2}\right)$

$m_1 = 1, 2, 3, \ldots$
$m_2 = 1, 2, 3, \ldots$
m_1 determines series
m_2 determines lines
R = 109,678 (OBSERVED VALUE)

SLIDE #11

Rydberg was aware that there was not only one set of lines, now called the Balmer series, but that the spectrum of hydrogen had several sets of lines in the invisible portions of the spectrum. In studying the relationship between these spectra he derived the empirical formula shown on slide number eleven. The constant R is called the Rydberg constant. The value of R was observed to be 109,678. If you can remember 6,7,8,9,10, you can remember this number. We now have a formula which not only gives us the lines of any one series, but gives us the lines of all the series. But we still do not know why these formulas work.

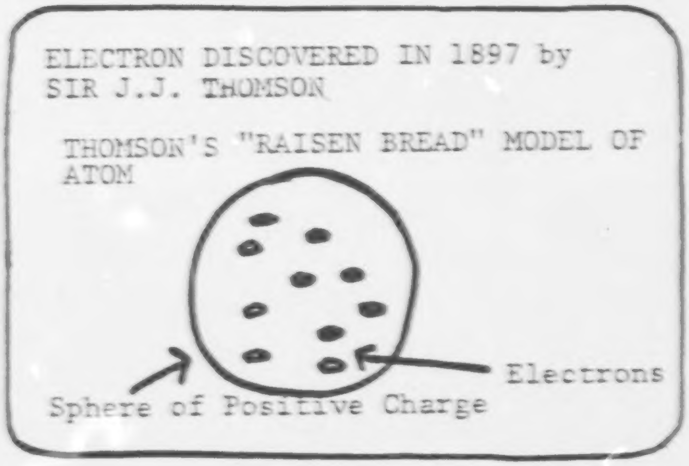
Look at slide number twelve. This is the end of this section of Module A1. As a result of studying this section, you should be able to explain what is meant by wavelength and you should know that light of different colors have different wavelengths. Also, you should know what the term spectrum means, and that the spectra of each element are different

1. Wavelength
2. Colors Relate to Wavelength
3. Spectrum
4. Spectra of Elements Different
5. Balmer
6. Rydberg
7. Empirical

SLIDE #12

from all others. In addition, you should be able to describe the contribution of Balmer and Rydberg to our understanding of the spectra of hydrogen and know what is meant by an empirical formula.

Advance your carrousel to slide number thirteen. Consequent to the discovery of the electron by Sir J.J. Thomson in 1897, several models of the structure of the atom were suggested. Sir Thomson suggested that the electrons were distributed within a sphere of positive charge, arranged in such a way that the mutual repulsion of their negative charge balanced the effect of the positive charge. This is sometimes referred to as Thomson's raisen bread model of the aton.


ELECTRON DISCOVERED IN 1897 by SIR J.J. THOMSON

THOMSON'S "RAISEN BREAD" MODEL OF ATOM

SLIDE #13

Look at slide number fourteen. In 1911, Lord Rutherford, working in the Cavindish Laboratories in England, performed his famous scattering experiment. This experiment proved that the atom was composed of a positive nucleus of great mass with the electrons somehow distributed about the

See Page 301A - Following

SLIDE #14

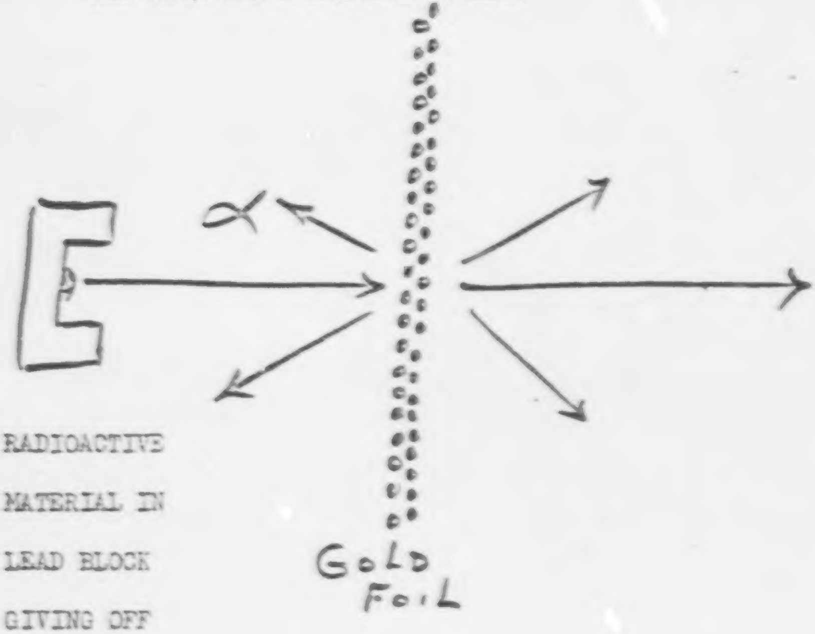
RUTHERFORD'S SCATTERING EXPERIMENT

1911

ALPHA PARTICLES BOUNCED OFF A GOLD FOIL

THE NUMBER SCATTERED IN VARIOUS DIRECTIONS SHOWED THAT

THE ATOM HAD A MASSIVE NUCLEUS



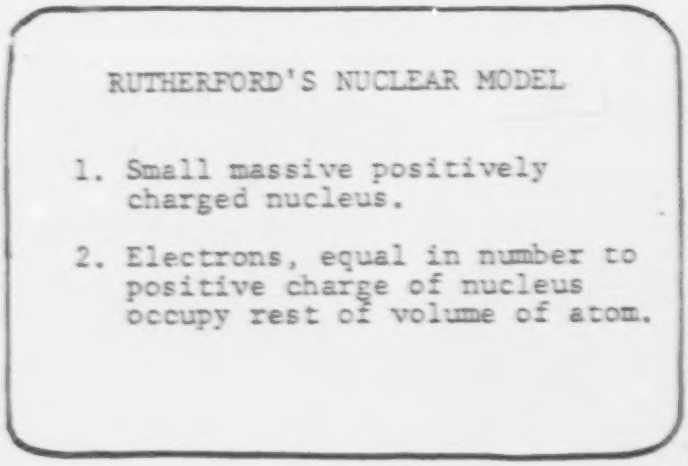
RADIOACTIVE
MATERIAL IN
LEAD BLOCK
GIVING OFF
ALPHA PARTICLES

SLIDE #14

nucleus. The experiment measured the deflection of alpha particles (projected from a radio-active source) by the atoms in a piece of gold foil. (Radioactivity had been discovered about twelve years before.) The degree of deflection recorded was inconsistant with the Thomson atom and demanded a massive nucleus of positive charge. It was evident that Thomson's raisen bread model was not sufficient to explain these observations.

Advance to slide number fifteen. Rutherford's nuclear model put the positive charge in the nucleus and distributed the electrons in the remainder of the volume of the atom. However, the problem remained of how to explain why the electrons simply didn't fall into the nucleus by virtue of the attraction of opposite electrical charges.

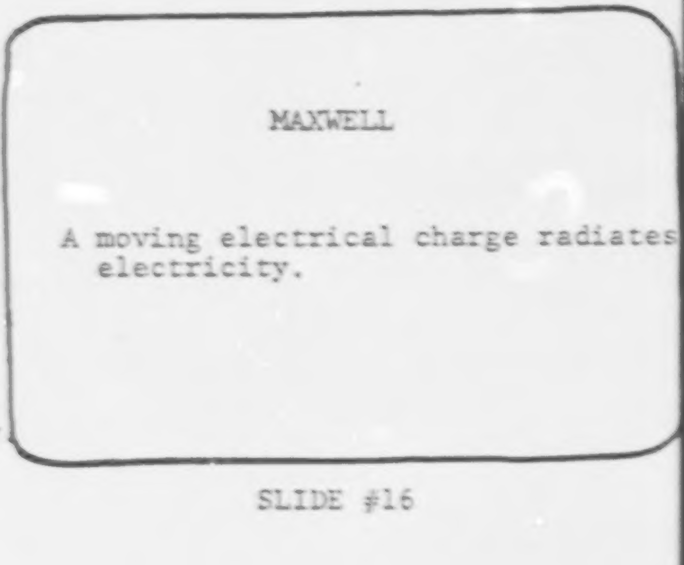
Look at slide number sixteen. A study of radio waves and the effects of moving charges led Maxwell to enunciate the much accepted physical law that moving charges radiate energy. As a consequence, physicists were



RUTHERFORD'S NUCLEAR MODEL

1. Small massive positively charged nucleus.
2. Electrons, equal in number to positive charge of nucleus occupy rest of volume of atom.

SLIDE #15



MAXWELL

A moving electrical charge radiates electricity.

SLIDE #16

reluctant to put electrons into motion in the atom, since they then would have to radiate energy, suggesting that they would eventually run out of energy and would fall into the nucleus. No one solved the problem, until Neils Bohr presented his celebrated theory on atomic structure.

Advance to slide number seventeen. In 1913 Bohr used the concept of the quantum that was introduced by Max Plank and Albert Einstein in 1905. This concept stated that light energy was available only as multiples of a basic unit of energy called a "quantum" and a "quantum" of energy was related to the frequency of the light. Einstein's equation states that the energy of the quantum, E, is equal to the frequency of the energy wave times a constant, now called Plank's constant. This is almost like saying you can't accelerate from zero to 60 by going through each speed in turn, but only by going 0mph, 5mph, 10mph, and so on in jumps!

PLANCK - EINSTEIN 1905

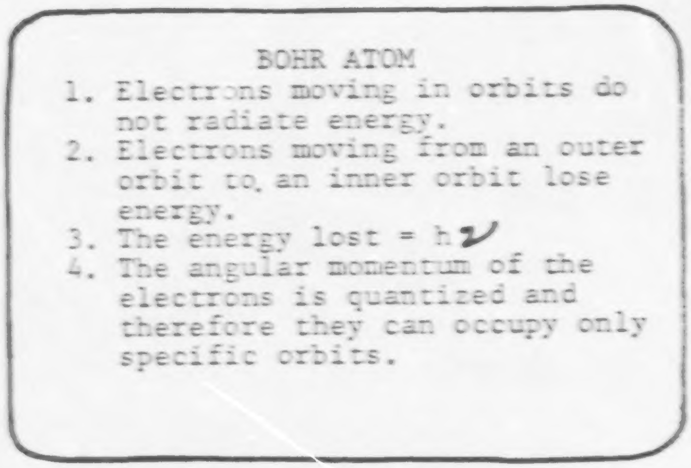
1. Radiant energy appeared only in standard "units" or blocks called "quanta".
2. The energy of a quantum was equal to the frequency of the radiant energy times a constant, h

$$E = h \times \nu$$

E = Energy
h = Planck's constant
ν = Frequency

SLIDE #17

Look at slide number eighteen. Bohr applied the concept of the quantum to his model of the atom by stating that the angular momentum of the electron moving about the nucleus was quantized; that is, it would take on only certain specific values. As a consequence the orbits themselves could have only certain specific values. Bohr also simply denied that the electron would radiate energy as it moved in its orbit, but if it jumped into a smaller orbit, it would lose energy. As a result of his four postulates, Bohr was able to write the formula for the frequency of light radiated when an electron went from one orbit to a smaller one.


BOHR ATOM

1. Electrons moving in orbits do not radiate energy.
2. Electrons moving from an outer orbit to an inner orbit lose energy.
3. The energy lost = $h\nu$
4. The angular momentum of the electrons is quantized and therefore they can occupy only specific orbits.

SLIDE #18

See Page 304A - Following

SLIDE #19

Now advance to slide number nineteen. Bohr's formula is given on slide number nineteen. It showed that the value of the Rydberg constant could be calculated from knowing the mass of the electron, the atomic number, the charge of the electron, the velocity of light, and Plank's constant. All of these values were well known and when the computation was

RYDBERG

$$\frac{1}{\lambda} = R_H \left(\frac{1}{N_1^2} - \frac{1}{N_2^2}\right)$$

BOHR

$$\frac{1}{\lambda} = \frac{2\pi M Z^2 E^4}{CH^3}\left(\frac{1}{N_1^2} - \frac{1}{N_2^2}\right)$$

M = MASS of ELECTRON

Z = ATOMIC NUMBER

e = CHARGE of ELECTRON

C = VELOCITY of LIGHT

h = PLANCK'S CONSTANT

SLIDE #19

made, the value was found to be 109,678.

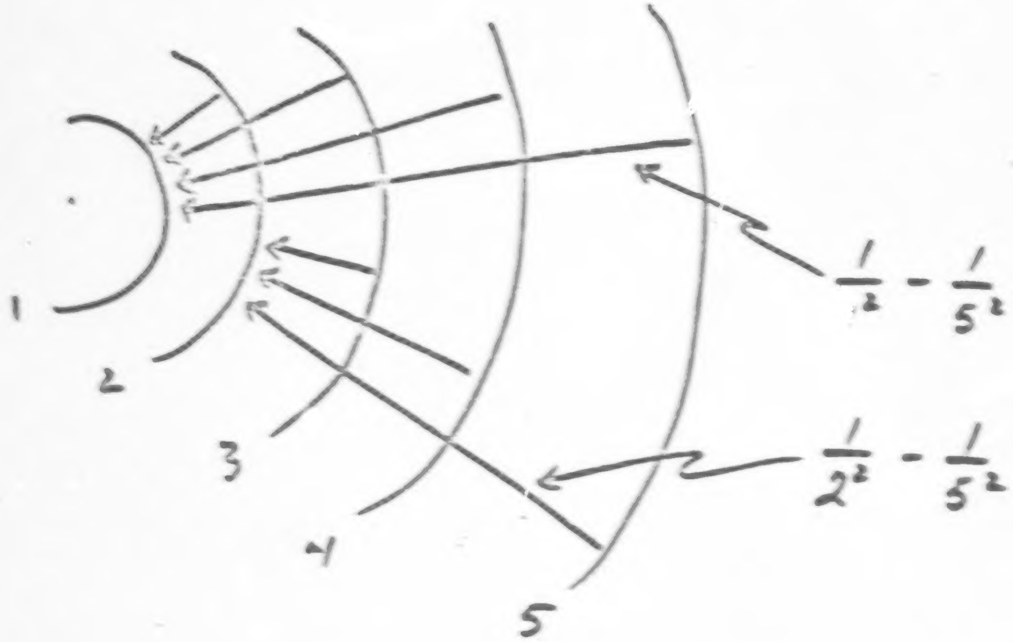
While it is not necessary that you be able to write these equations, you should be aware that from purely theoretical considerations, Bohr came up with a value for the Rydberg constant which agreed exactly with observation. This forced the acceptance of his theory.

See Page 305A - Following

SLIDE #20

Advance to slide number twenty. If we imagine the specific orbits as drawn we see that electrons jump from orbits 2, 3, 4, . . . into orbit one giving us one series of energy differences, while electrons jumping from orbits 3, 4, 5, . . . into orbit two, gives us another series. Since the electron is attracted to the positive charge of the nucleus it must be given energy to put it into a more distant orbit. It loses that energy when it jumps into a smaller orbit. These energy levels of the electron are based on more factors than just the orbit or shell, as we will see later. Here, however, note that our understanding of the electron configuration was due to the study of light.

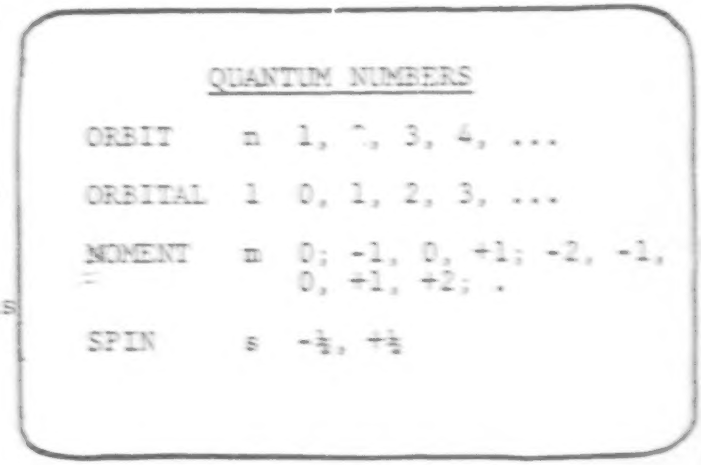
$$\frac{1}{\lambda} = R\left(\frac{1}{N_1^2} - \frac{1}{N_2^2}\right)$$


1
2
3
4
5
$\frac{1}{1^2} - \frac{1}{5^2}$
$\frac{1}{2^2} - \frac{1}{5^2}$

SLIDE #20

This picture of the atom is, as you may know, over-simplified. During the course of the years following the announcement of Bohr's theory, scientists came to understand that the energy possessed by an electron was described by four numbers, not just the "n" given in the Rydberg and Bohr formula to specify the shell occupied. These numbers which characterize each of the electrons are called "quantum numbers". The energy of an electron was dependent upon the values of these four quantum numbers. The mathematics involved was called quantum mechanics or wave mechanics. The wave mechanics equation for all atoms was derived by Erwin Schrodinger in 1925. This is the famous Schrodinger wave equation. It is a complex partial differential equation that could not be solved except for the most simple case until the advent of high speed computers. Let us look at some of the conclusions that were drawn from it.

Look at slide number twenty-one. The energy of each electron is described by four quantum numbers called the "n",



QUANTUM NUMBERS

ORBIT	n	1, 2, 3, 4, ...
ORBITAL	l	0, 1, 2, 3, ...
MOMENT	m	0; -1, 0, +1; -2, -1, 0, +1, +2; .
SPIN	s	-½, +½

SLIDE #21

1, m, and s or spin quantum numbers. Each quantum number can have only a specific set of values. In an atom no two electrons can have the same set of quantum numbers. This statement is called the Pauli Exclusion Principle. The numbers for each follow simple rules for designation. The "n" quantum number takes on whole number values starting at $n = 1$, $n = 2$, and so on. The "1" quantum number has as many values as the value of the "n" quantum number. When $n = 1$, 1 has only one value, namely zero. When $n = 2$, 1 has the values 0 and 1; when $n = 3$, $1 = 0$, 1, and 2. The "m" quantum number takes of values centered on 0 to $\pm \ell$. For example, when $\ell = 0$, $m = 0$. When $\ell = 2$, m can take on the values -2, -1, 0, +1, +2, and so on. The spin quantum number can only take on the value of + or -½.

Look at slide number twenty-two. You can see how the possible sets of quantum numbers are formed. Each electron has a different set of numbers. As the shells get larger, the possible values for the quantum numbers increase and we get more electrons in that shell.

See Page 307A - Following

SLIDE #22

SLIDE #22

1st SHELL

2nd SHELL

SHELL M	1	1	2	2	2	2	2	2	2	2
l	0	0	0	0	1	1	1	1	1	1
m	0	0	0	0	-1	-1	0	0	1	1
S	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2

TWO ELECTRONS

EIGHT ELECTRONS

Advance to slide number twenty-three. This is the complete set of quantum numbers for all the 18 electrons in the third shell of an atom. Can you write the quantum numbers for the electrons in the fourth shell? Note that the value of the "n" quantum number will be 4 instead of 3 for these 18 sets of numbers, but you must now add the set of numbers where the value of "l" is 3. Make yourself a diagram and see if you can do it.

See Page 308A - Following

SLIDE #23

Advance to slide number twenty-four.

See Page 308B - Following

SLIDE #24

Look at slide number twenty-five. You can see now how each of the values for the quantum numbers is derived. Given the value of $n = 4$, ℓ can have the value of 0, 1, 2, and 3; m can have only the values of -1 to 0 to +1; and s only the values of $+\frac{1}{2}$ or $-\frac{1}{2}$. I will not ask you again to give me the quantum numbers of a specific electron; however, it is important that you see what these numbers are and how they are determined. But most important of all, you should realize that no two electrons have the same quantum numbers.

See Page 308C - Following

SLIDE #25

	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
L	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
	0	0	-1	-1	0	0	+1	+1	-2	-2	-1	-1	0	0	1	1	2	2
S	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2	-1/2	+1/2

n	4	4	4	4	4	4			
l	3	3	3	3	3	3			
m	-3	-3							
s	+1/2	-1/2							

SLIDE #24

N	4	4	4	4	4	4	4	4	4	4	4	4	4	4
l	3	3	3	3	3	3	3	3	3	3	3	3	3	3
m	-3	-3	-2	-2	-1	-1	0	0	+1	+1	+2	+2	+3	+3
S	$-1/2$	$+1/2$	$-1/2$	$+1/2$	$-1/2$	$+1/2$	$-1/2$	$-1/2$	$-1/2$	$+1/2$	$-1/2$	$+1/2$	$-1/2$	$+1/2$

Advance to slide number twenty-six. After completing this part of the unit you should be able to describe the Thomson atom, relate the theories of Maxwell regarding moving charges, and of Plank and Einstein regarding quanta of energy to the problem of electron structure in the atom. You should know what Bohr's four postulates are and why his theory was accepted in spite of apparent contradictions with accepted principles. You should relate the name Schrodinger to the development of the electron theory. You should be able to name the four quantum numbers and show how the values are designated. Finally, you should be able to express the Pauli exclusion principle.

Thompson Atom
Maxwell
Einstein & Planck
Bohr
Bohr Atom - Four Postulates
Schrodinger Wave Equation
Four Quantum Numbers
Pauli Exclusion Principle

SLIDE #26

Look at slide number twenty-seven. We have called the principle quantum number the shell quantum number. The "l" quantum number corresponds to our concept of different shapes of the electron orbits within the shell. The "m" quantum number corresponds to a concept of magnetic property of the electron, while the spin quantum

m = shell quantum number
ℓ = orbital quantum number

ℓ	
0	s orbital
1	p orbital
2	d orbital
3	f orbital

SLIDE #27

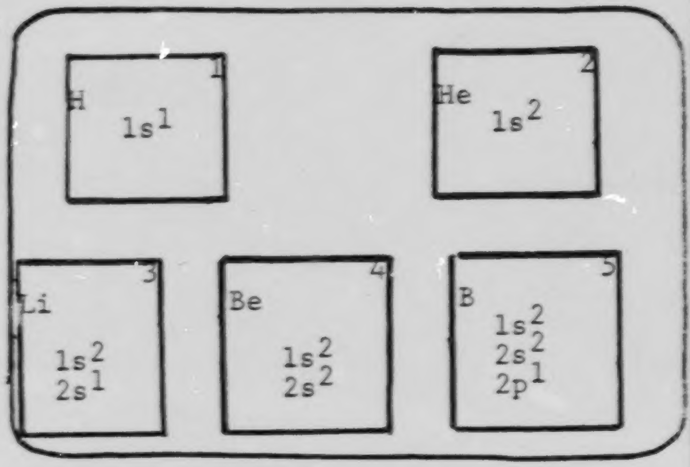
number refers to the spin of the electron. The differences in the spectra of various energy levels of atoms gave rise to the names sharp, principle, diffuse, and fine for various series or types of spectra. These spectral types now seem to correspond to the different values of the "l" quantum number. From the designation of the shell and orbital number comes a system of notation describing the electrons in an atom.

Advance to slide number twenty-eight. We show here how the orbitals are designated. For example, where $n = 2$, and $\ell = 1$, we call this the 2p orbital and we see that there can be six different electrons in this orbital.

See Page 310A - Following

SLIDE #28

Look at slide number twenty-nine. We will not fill in the squares of the periodic chart with the designations of the electrons in the electron configuration of each atom. Remember, each element differs from the preceeding one on the chart by having one more positively charged proton and, consequently, one more electron. Hydrogen has only one electron so we call that $1s^1$, that is, it is in the



SLIDE #29

n	1	2	2	3	3	3
l	0	0	1	0	1	2
m	0	0	-1, 0, +1	0	-1 0 +1	-2 -1 0 +1 +2
S	+ ½ − ½	+ ½ − ½	+ ½ − ½	+ ½ − ½	+ ½ − ½	+ ½ − ½
POSSIBLE NUMBER OF ELECTRONS	2	2	6	2	6	10
NAME OF ORBITAL	1S	2S	2P	3S	3P	3d

shell number 1. Helium has two s electrons and both of these are in the #1 shell. The electron configuration is designated as $1s^2$, that is, there are two s electrons in the #1 shell. Lithium has three electrons. These include the two in the 1s orbital and one more. The one more is in the 2s orbital. The electron configuration of lithium, then, is designated as $1s^2 2s^1$. Beryllium has four electrons so the fourth will fit into the 2s orbital and the electron configutation for Beryllium is $1s^2 2s^2$. Now that the 2s orbital is filled the next electron will go into the 2p orbital. Boron has five electrons. Its electron configuration is $1s^2 2s^2 sp^1$. Now there are six electrons which can fit into the 2p orbital. On a sheet of paper, designate the electron configuration for all the elements from atomic numbers 6 to 20.

Now advance to slide number thirty. In this slide you will find the correct values for elements 6 through 30. Compare the values that you obtained with those shown on slide number thirty.

See Page 311A - Following

SLIDE #30

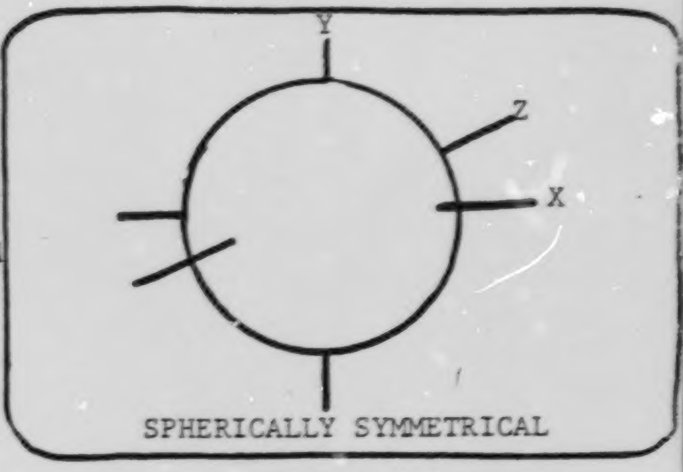
1 $1S^1$							$1S^2$
3 $1S^2$ $2S^1$	4 $1S^2$ $2S^2$	5 $1S^2$ $2S^2$ 2P1	6 $1S^2$ $2S^2$ 2P2	7 $1S^2$ $2S^2$ 2P3	8 " " 2P4	9 " " 2P5	10 " " 2P6
11 $1S^2$ $2S^2$ 2P6 $3S^1$	12 " " " $3S^2$	13 " " " $3S^2$ $3P^1$	14 " " " " 3P2	15 " 3P3	16 " 3P4	17 " 3P5	18 " 3P6
19 $1S^2$ $2S^2$ 2P6 $3S^2$ 3P6 $4S^1$	20 " $4S^2$						

Now advance to slide number thirty-one. In slide number thirty-one you will see the Periodic Chart in terms of orbitals being filled. The periodicity which the early chemists recognized among the properties of the elements is reflected in their similarities of electron configuration.

See Page 312A - Following

SLIDE #31

Advance to slide number thirty-two. The Schrodinger equation allows us to compute the probability of locating an electron at a given point in space around the nucleus. If we draw a three dimensional diagram showing the most likely positions occupied by the electron we get a picture of what is called a charge cloud. Slide number thirty-two shows the cloud for an s electron. Note that the cloud is spherical about the nucleus.



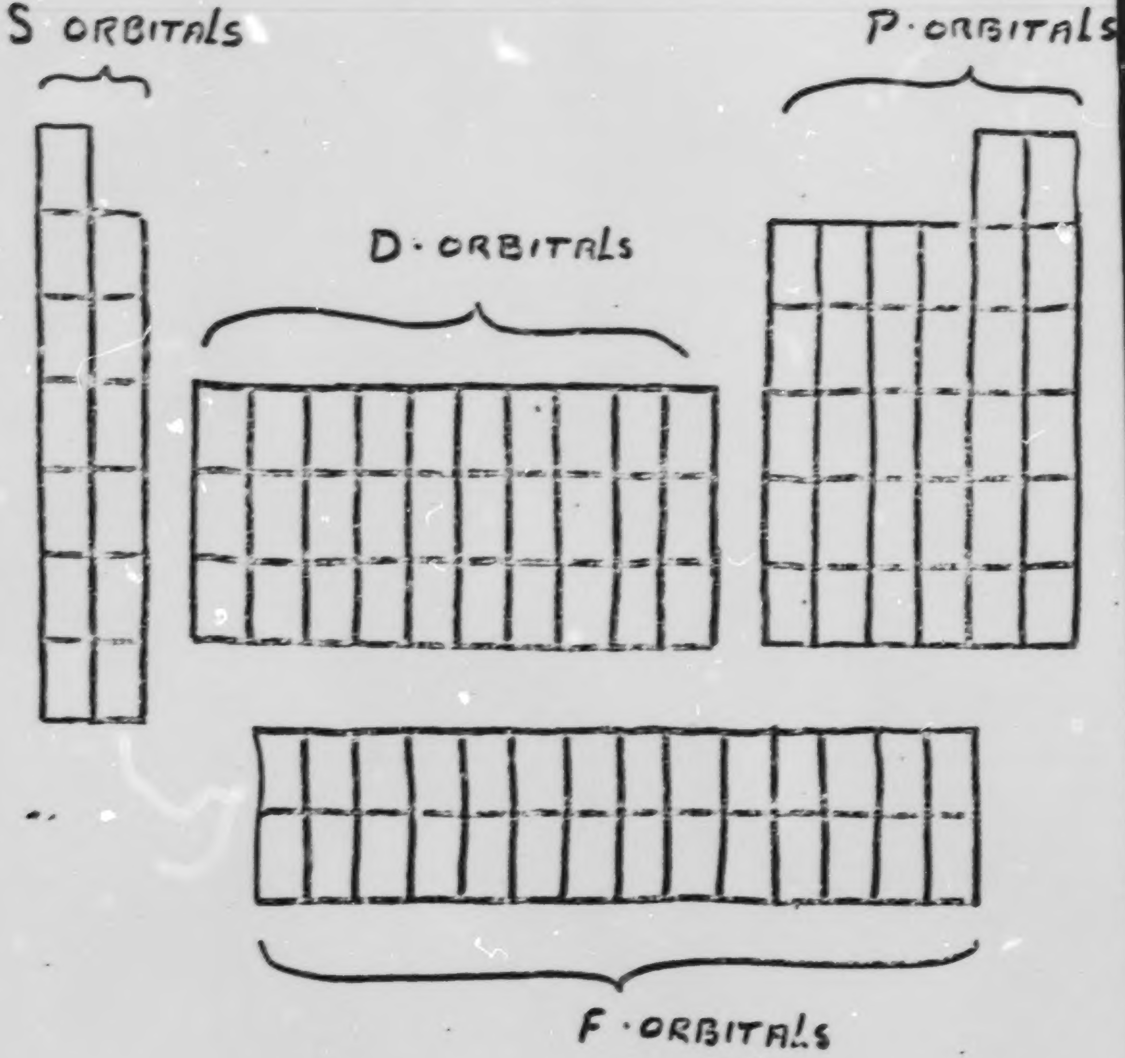
SLIDE #32

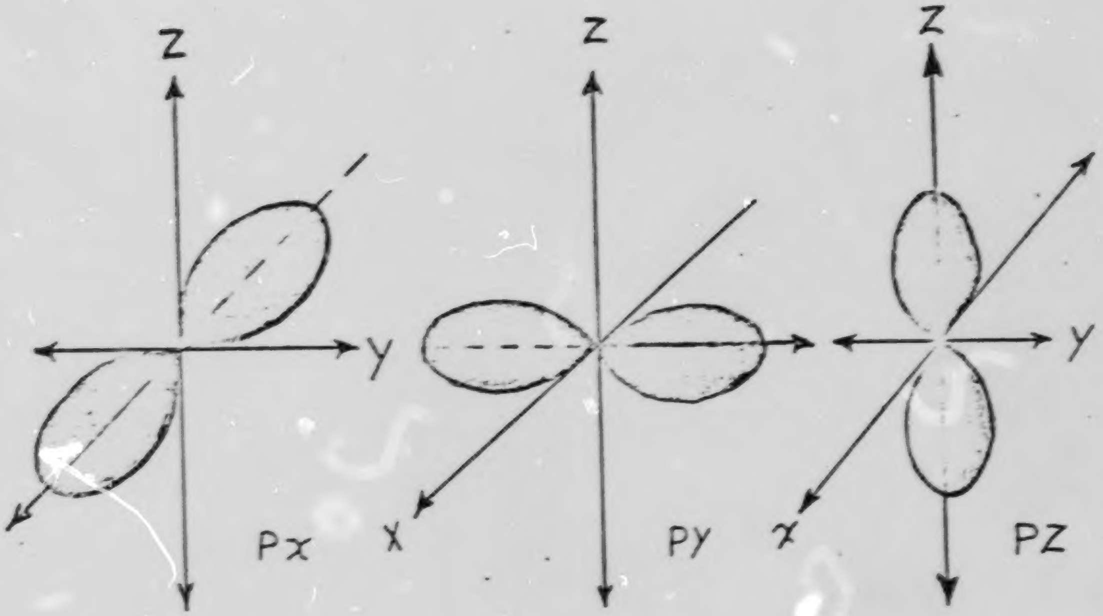
Look at slide number thirty-three. There is a diagram of a P orbital. There are three P orbitals, each at right angles to the other two. The orbital depicted here has two lobes, but that does not mean that two electrons occupy the orbital. One electron in a P orbital would have the same distribution

See Page 312B - Following

SLIDE #33

SLIDE #31


S ORBITALS
P·ORBITALS
D·ORBITALS
F·ORBITALS


Z
Y
Px
Z
X
Py
Z
Y
x
PZ

SLIDE #33

of points where it might be found.

Look at slide number thirty-four. When elements combine by sharing electrons, the shapes of the orbitals change. In the case of an s-s, as for example, in H_2, the orbitals distort slightly. In the case of an s-p bond, the P orbital, which had been symmetrical about the nucleus is now distributed more on the side toward the bonded atom. This means that the charge is no longer symmetrical about the nucleus.

See Page 313A - Following

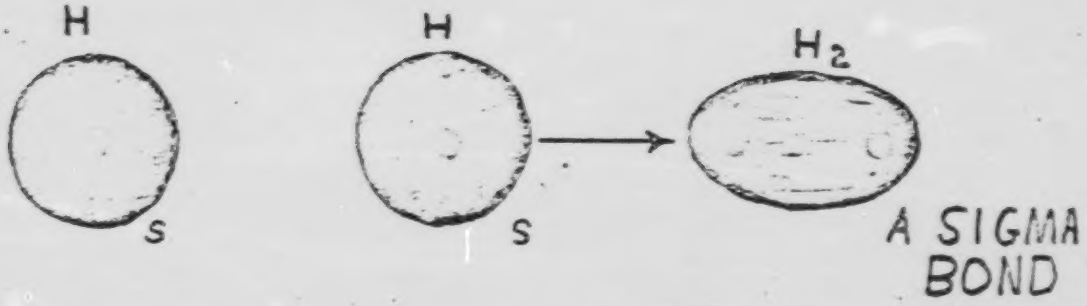
SLIDE #34

Look at slide number thirty-five. This is a representation of a water molecule. The 3 P orbitals of oxygen are at right angles to each other before uniting with the hydrogen. The two hydrogens unite with the two p orbital electrons, forming s-p bonds, but the positive charges of the hydrogen nuclei repel each other and force the orbitals out to 104 degrees 28 minutes. Since the electron cloud is not symmetrical about the nucleus, the molecule has an uneven spatial charge distribution. It is called a dipole since it has two charged areas, one positive and one negative.

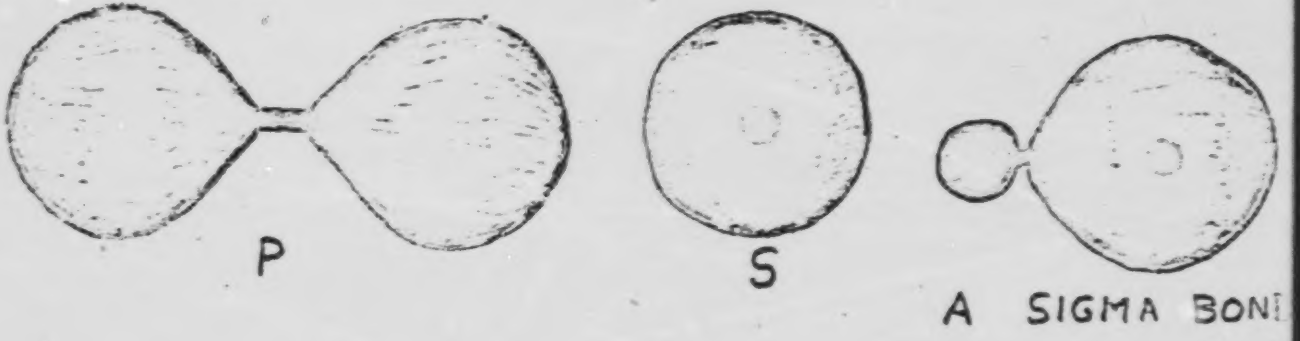
See Page 313B - Following

SLIDE #35

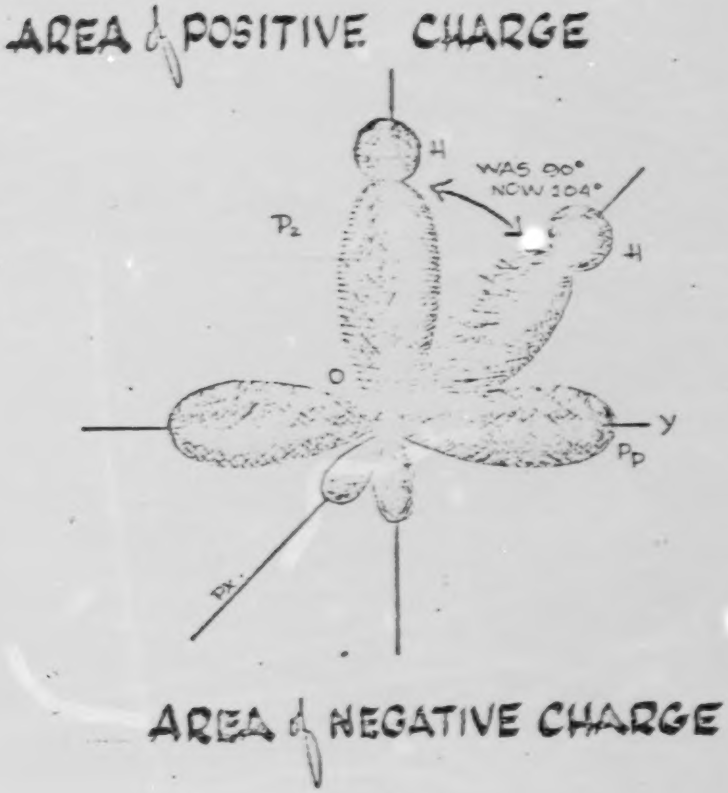
FROM TWO ORBITALS


H
S
H
S
H_2
A SIGMA BOND

FROM S & P ORBITALS (END TO END OVERLAP)


P
S
A SIGMA BON

SLIDE #34


AREA of POSITIVE CHARGE
H
WAS 90°
NOW 104°
Pz
H
O
Y
Pp
Px
AREA of NEGATIVE CHARGE

SLIDE #35

Advance to slide number thirty-six. Since the oxygens have large electron clouds about them, the oxygen end of the molecule is slightly negative, while a positive area occurs opposite the s-p bonds. Water molecules arrange themselves in chains and lattices according to these charges and form ice (snow) crystals of great symmetry. The dipolar nature of water explains many of the anomalous features of this compound such as its high boiling point (the charges help hold the molecules together) and its properties as a solvent. If it were not for these properties, H_2O would not exist in the form we take for granted and life on earth could not exist.

See Page 314A - Following

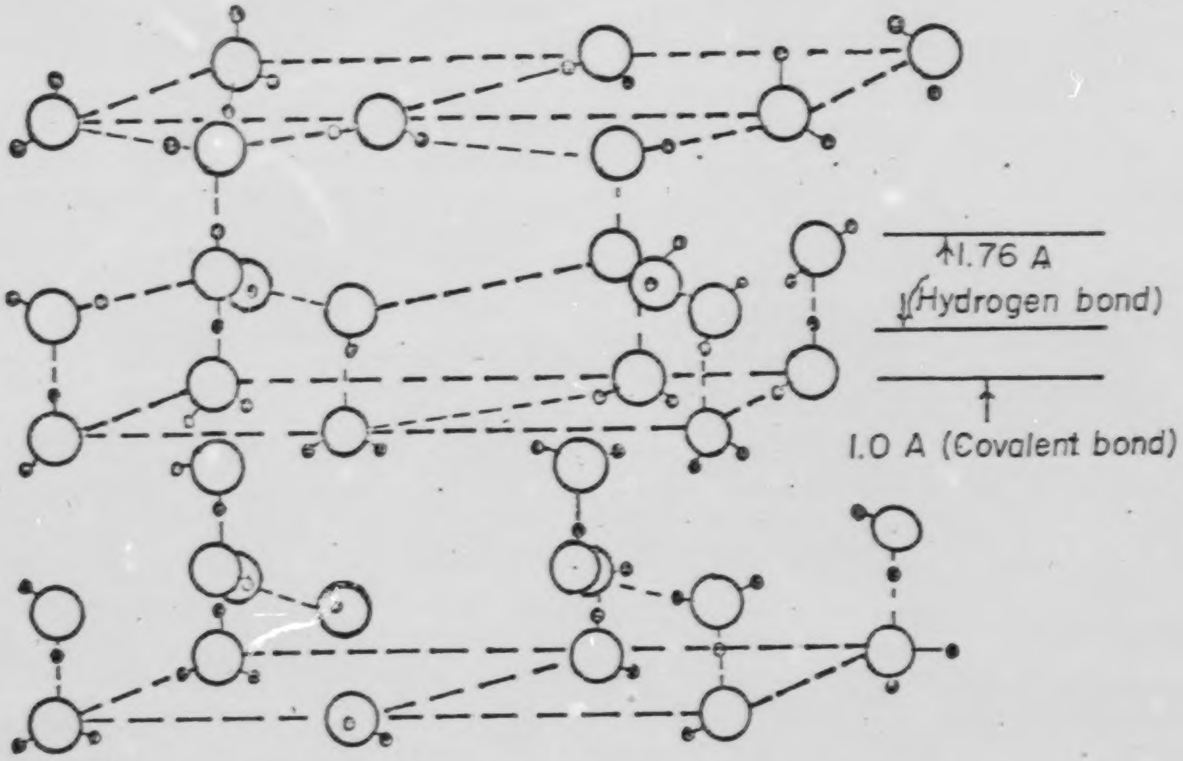
SLIDE #36

Advance to slide number thirty-seven. Sometimes electrons of a shell move from one orbital into another and cause the formation of hybrid orbitals. The example of the electrons in carbon is the most important. The electron configuration in carbon is designated as $1s^22s^2sp^2$. This gives us only two p electrons which can be shared with other atoms. If, however, one of the

See Page 314B - Following

SLIDE #37

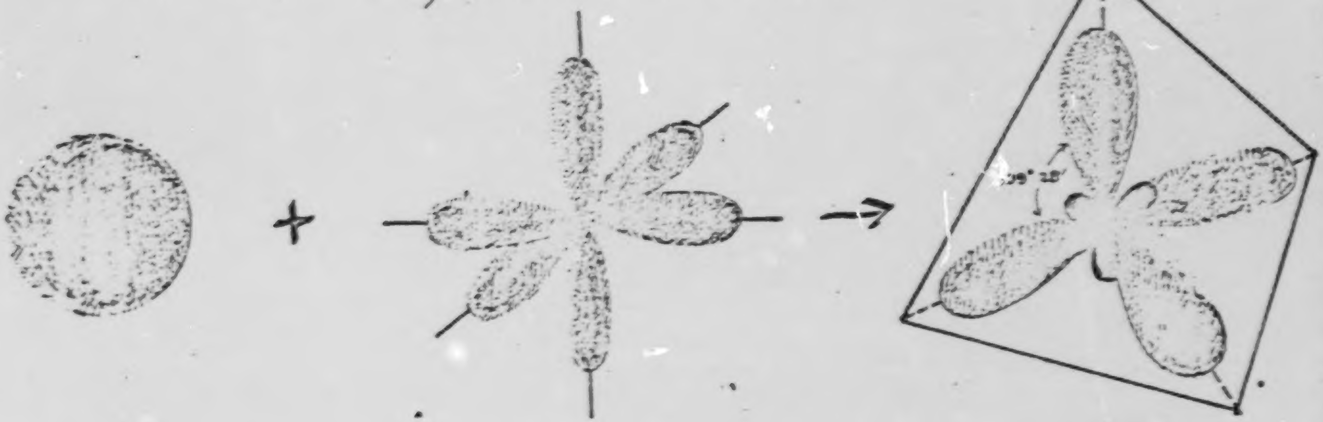
ICE CRYSTAL STRUCTURE


1.76 A
(Hydrogen bond)
1.0 A (Covalent bond)

SLIDE #36

SLIDE #37

SP^3 HYBRIDIZATION



ONE S + THREE P → FOUR SP^3

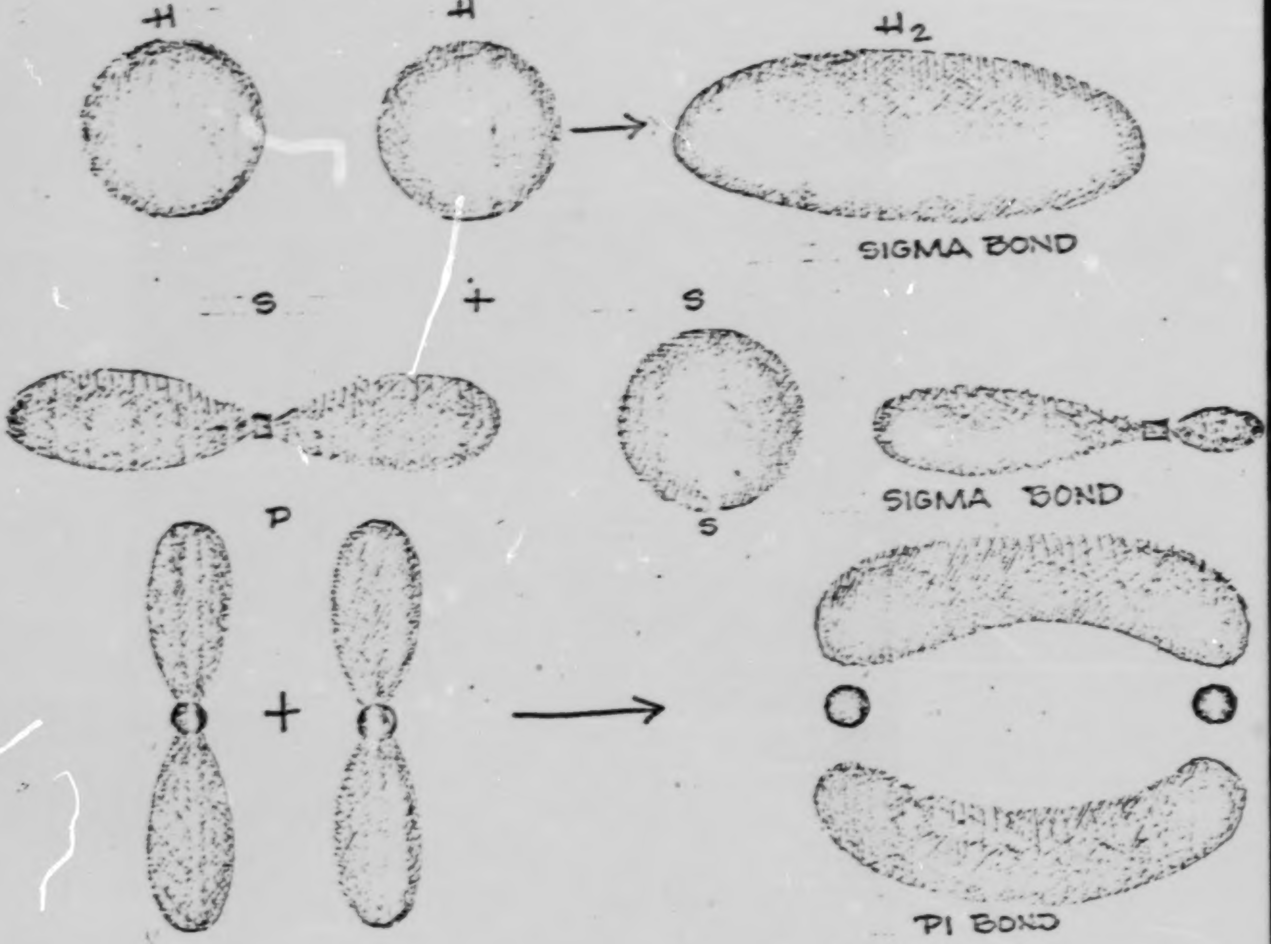
electrons from the 2s orbital moves into the third 2p orbital, we would have four electrons which could be shared, one in the 2s level and three in the 2p level. When these electrons are shared with electrons of other atoms the carbon has a stable eight electron outer shell configuration and a stable compound is formed. It turns out that there is no difference in the shape of any of the four orbitals. In other words, we don't get a sphere and three dumbbell shaped orbitals. The s electron and the three p electrons form a new type orbital, called an sp^3 orbital. These combination orbitals are called hybrid orbitals. Since the orbitals are all the same in shape and charge, the electron clouds arrange themselves so as to be as far away from each other as possible. This results in the sp^3 orbitals pointing at the corners of a tetrahedron.

Look at slide number thirty-eight. Two atoms which unite by sharing electrons can be represented, as shown on slide number thirty-eight, as the overlapping of two s orbitals, as in

See Page 315A - Following

SLIDE #38

SLIDE #38


H
H
H_2
SIGMA BOND
s
+
s
p
s
SIGMA BOND
+
PI BOND

H_2, or the overlapping of s and p or orbitals as in water. Such overlapping bonds are called sigma bonds. It can also occur that atoms will share electrons through the overlapping of two p orbitals. Remember that the dumbbell shape of the orbital represents the location of only one electron, not two. The overlapping of a pair of p orbitals is called a pi bond. The carbon atom forms this type of bond with oxygen in the formation of CO_2.

Advance your carrousel to slide number thirty-nine. The carbon atom can form this type of bond with other carbon atoms. On this slide you can see the pi bonding between the carbon atoms. The upper diagram shows two carbon atoms with one sigma bond and one pi bond. This is a molecule of ethylene. The lower diagram shows two carbon atoms with one sigma and two pi bonds between them. This is a molecule of acetylene.

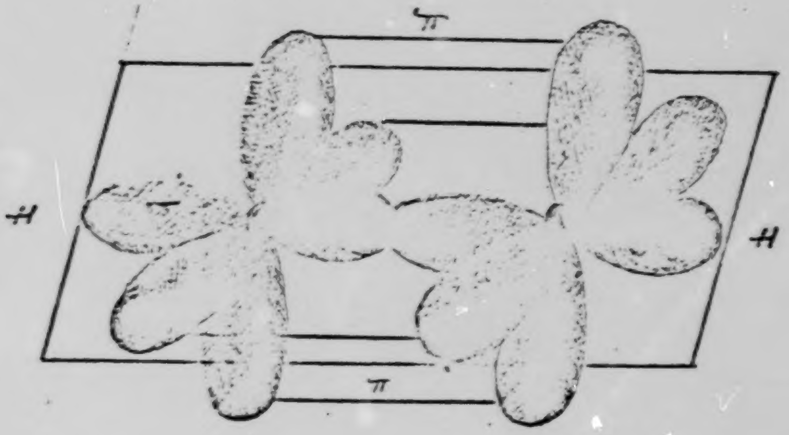
See Page 317A - Following

SLIDE #39

The distribution of charge clouds in molecular bonding is computed by high speed computers. For the equations the chemist can determine many of the

SLIDE #39

BONDING of ETHYLENE & ACETYLENE



physical and chemical properties of the compounds formed. At this stage, chemistry, mathematics, and physics become one. The structure and properties of matter, all the physical world about you, reduces to a study of electron clouds and molecular configuration.

Look at slide number forty. Upon completing this section of the module, you should be able to relate electron configuration to the periodic chart, recognize the shapes of s and p orbitals, explain hybridized orbitals, distinguish sigma bonds and pi bonds, and explain the dipolar nature of water.

1. Electron configuration and Periodic Chart.
2. Shapes of electron orbitals S & P.
3. Shape of hybridized SP^3 orbital.
4. Shape of Sigma bonds.
5. Shape of Pi bonds.
6. Explain dipolar nature of water.

SLIDE #40

MODULE A-1 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the MODULE A-1 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE A-1 as well as to the completion of the problem set. Those pages are: 39, 40, 49, 139-146, 151-165, 168-180, 187, 188, 192, 193, 197, and 298.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown.

Page	Problem
148	3
165	2, 5, 6
198	7

MODULE A-1 PROBLEM SET SOLUTIONS

Page Problem

148 (3) There are 18. They are:

16-12-16
16-13-16
16-14-16
17-12-17
17-13-17
17-14-17
18-12-18
18-13-18
18-14-18
16-12-17
16-12-18
16-13-17
16-13-18
16-14-17
16-14-18
17-12-18
17-13-18
17-14-18

165 (2) Their quantum numbers would be the same, and the electrons would have opposite spins.

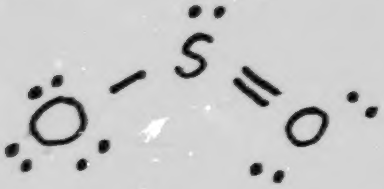
165 (5) Ar $1s^2 2s^2 2p^6 3s^2 3p^6$
K is the same as Ar plus $4s^1$
S_1 $1s^2 2s^2 2p^6 3s^2 3p^2$
Fe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

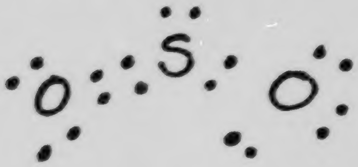
165 (6)

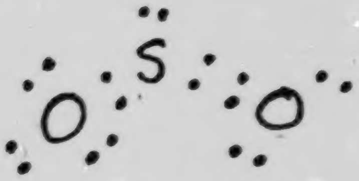
n Principle	1 Azimuthal	m_1 Magnetic	ms Spin	Electron Notation
4	0	0	$\pm\frac{1}{2}$	4s
4	1	-1	$\pm\frac{1}{2}$	
4	1	0	$\pm\frac{1}{2}$	4p
4	1	+1	$\pm\frac{1}{2}$	
4	2	-2	$\pm\frac{1}{2}$	
4	2	-1	$\pm\frac{1}{2}$	
4	2	0	$\pm\frac{1}{2}$	4d
4	2	+1	$\pm\frac{1}{2}$	
4	2	+2	$\pm\frac{1}{2}$	

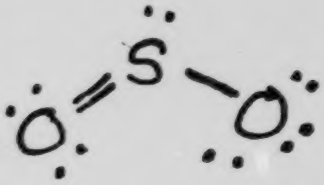
Continued . . .

Page	Problem
198	(7)









Name ______________________

MODULE A1 - 1 EXAMINATION

1. Write a short sentence describing the contribution of each of the following to our understanding of the electron structure of the atom:
   - a. Balmer
   - b. Rydberg
   - c. Hertz-Maxwell
   - d. Thomson
   - e. Rutherford
   - f. Planck
   - g. Einstein
   - h. Bohr (state four postulates)

2. Write the quantum numbers for the third shell electrons in $_{18}Ar$.

3. Give the electron designation for the element $_{18}Ar$.

4. Diagram a sigma bond of an s orbital and a p orbital.

5. Draw a water molecule and explain its characteristics.

MODULE A1 - 1 EXAMINATION SOLUTION SET

1. a. Balmer's investigation attempted to determine whether there was a relationship between the lines in the visible spectrum produced by hydrogen gas and the wavelengths of those lines. The relationship he found was:

$$\lambda = \frac{m^2}{m^2 - \text{A POSITIVE INTEGER}}$$

His formula predicts what the wavelengths of the various lines should be.

b. Rydberg derived the Rydberg constant (109,678) and an empirical formula for the relationship between hydrogen and its spectral lines. This formula would provide the lines in all series not just those for hydrogen.

c. Hertz - Maxwell made a study of radio waves and the effects of moving charges. This led him to the law that moving charges radiate energy.

d. Thomson derived a model of the atom which was called the raisen bread model. He also calculated the charge to mass ratio of the electron.

e. Rutherford derived a nuclear model of the atom with a positive charge in the nucleus and electrons distributed in the remainder of the volume of the atom.

f. Planck and Einstein introduced the concept of the quantum which states that light energy is available only in multiples of a basic unit of energy called a quantum. They also stated that a quantum of energy was related to the frequency of light.

g. Einstein -- see "f" above. Also, he derived an equation which states that the energy of a quantum, E, is equal to the frequency of the energy wave times a constant.

h. Bohr's four postulates were:

(1) The electrons in atoms are located in orbits, or energy levels, around the nucleus.
(2) The electrons in orbits closest to the nucleus are of lower energy than those in orbits farther away from the nucleus.
(3) Every electron in an atom may have only certain allowed energies. This energy determines what orbit the electron occupies.
(4) Electrons can move from one orbit to another. To do this, an electron must gain or lose a certain amount of energy, a quantum of energy.

Exam Solution Set
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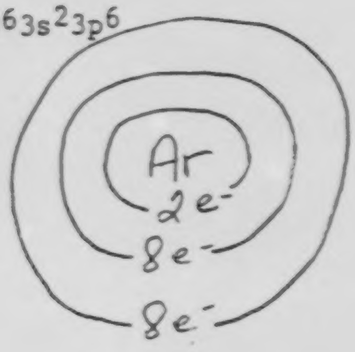
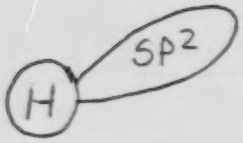
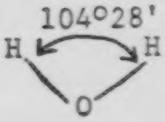
2. $3s^2 3p^6$

3. $1s^2 2s^2 2p^6 3s^2 3p^6$



4. 

5. 

The electrons H's in a water molecule unite with two p orbitals of the oxygen molecule forming s-p bonds. The positive charges of the H nuclei repel each other and force the orbital to the bond angle shown above. This allows H_2O molecules to arrange themselves in chains and lattices to form snow and ice crystals of great symmetry. This dipolar nature explains H_2O's high boiling point and solvent properties.

Name ____________________

MODULE A1 - 2 EXAMINATION

1. Write a short sentence describing the contribution of each of the following to our understanding of the electron structure in the atom:

   a. Balmer

   b. Rydberg

   c. Hertz-Maxwell

   d. Thomson

   e. Rutherford

   f. Planck

   g. Einstein

   h. Bohr (state four postulates)

2. Write the quantum numbers for the 2nd shell electrons in $_{17}Cl$.

3. Give the electron designation for the element $_{17}Cl$.

4. Diagram a sigma bond of an s orbital and a p orbital.

5. Draw a water molecule and explain its characteristics.

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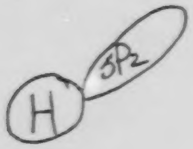
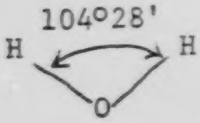
MODULE A1 - 2 EXAMINATION SOLUTION SET

1. See Module A1-1 #1 examination solution set.
2. $2s^2 2p^6$
3. $1s^2 2s^2 2p^6 3s^2 3p^5$
4.



5.



The electron H's in a water molecule unite with two p orbitals of the oxygen molecule forming s-p bonds. The positive charges of the H nuclei repel each other and force the orbital to the bond angle shown above. This allows H_2O molecules to arrange themselves in chains and lattices to form snow and ice crystals of great symmetry. This dipolar nature explains H_2O's high boiling point and solvent properties.

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Name ______________________

MODULE A1 - 3 EXAMINATION

1. Define the following terms:
   - a. quantum number
   - b. sigma bond
   - c. pi bond
   - d. dipolar molecule
   - e. wavelength
   - f. electron configuration

2. What are the four postulates attributed to Bohr?

3. What is the relationship between alpha particles and Rutherford?

4. What types of orbitals would you find in an $n=4$ energy level?

5. Explain the meaning of $2p^5$.

MODULE A1 - 3 EXAMINATION SOLUTION SET

1. a. The principle quantum number is the number used to designate the principle energy levels that an electron may occupy in an atom.

   b. Sigma bonds are bonds which are completely symmetrical.

   c. Pi bonds are bonds which are not symmetrical.

   d. See Module A1-1 #5 examination solution set.

   e. Wavelength is the distance between crests of successive waves (the distance from a given point on a wave to the same point on the following wave).

   f. The way the electrons are arranged, at the various energy levels, for a given atom.

2. Bohr's four postulates were:

   (1) The electrons in atoms are located in orbits, or energy levels, around the nucleus.
   (2) The electrons in orbits closest to the nucleus are of lower energy than those in orbits farther away from the nucleus.
   (3) Every electron in an atom may have only certain allowed energies. This energy determines what orbit the electron occupies.
   (4) Electrons can move from one orbit to another. To do this, an electron must gain or lose a certain amount of energy, a quantum of energy.

3. In 1911 Rutherford performed the scattering experiemnt. This experiment measured the deflection of alpha particles (projected from a radioactive source) by the atoms in a piece of gold foil.

4. s, p, d, f.

5. $2p^5$ ← 5 electrons

   p subshell

   principle quantum number

Name ______________________

MODULE A1 - 4 EXAMINATION

1. How many electrons are there in the configuration $4s^23d^{10}4p$?

2. In the configuration given above, to which subshells are the electrons assigned and how many are assigned to each of the subshells?

3. Define each of the following terms:

   a. Pauli exclusion principle

   b. Principle quantum number

   c. spin quantum number

   d. emission spectrum

4. Describe the contribution made by each of the following to our knowledge of the electron structure of the atom:

   a. Balmer

   b. Bohr

   c. Einstein

   d. Thomson

5. Draw and describe a dipolar molecule.

MODULE A1 - 4 EXAMINATION SOLUTION SET

1. 18

2. 2 electrons to the s sublevel;
10 electrons to the d sublevel;
6 electrons to the p sublevel.

3. a. The Pauli exclusion principle states that no two electrons in a given atom can have the same set of quantum numbers.

   b. The principle quantum number is the number used to designate the principle energy levels that an electron may occupy in an atom.

   c. The spin quantum number describes the spin orientation of the electron.

   d. The emission spectrum is the displayed wavelength distribution of light coming from an emitting source.

4. a. - d. See Module A1-1 #1 examination solution set.

5. See Module A1-1 #5 examination solution set.

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Name ______________________

MODULE A1 - 5 EXAMINATION

1. Diagram a sigma bond of an s orbital and a p orbital.

2. Discuss what makes H_2O a unique molecule.

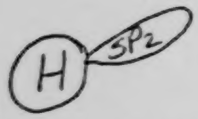
3. Define the following terms:
    a. pi bond
    b. sigma bond
    c. hybridization
    d. quantum numbers
    e. electron configuration
    f. wavelength
    g. spectrum

4. What is meant by the statement "Each element has a unique spectra"?

5. Explain the relationship between electron configuration and the Periodic Table.

6. What are Bohr's four postulates?

MODULE A1 - 5 EXAMINATION SOLUTION SET

1. 

2. See Module A1-1 #5 examination solution set.

3. a. Pi bonds are bonds which are not symmetrical.

   b. Sigma bonds are bonds which are completely symmetrical.

   c. Hybridization is sigma bonding that involves more than one orbital on the same atom.

   d. The principle quantum number is the number used to designate the principle energy levels that an electron may occupy in an atom.

   e. The way that the electrons are arranged, at the various energy levels, for a given atom.

   f. Wavelength is the distance between crests of successive waves (the distance from a given point on a wave to the same point on the following wave).

   g. A spectrum is a displayed wavelength distribution.

4. Each element, when subjected to proper testing techniques, will display its own characteristic line spectrum. This spectrum is different from all other elements.

5. Each successive element in the periodic table has one additional electron. Those elements having eight electrons in their outer shell occupy the extreme right hand side of the table and are known as the inert gases.

6. Bohr's four postulates were:

   (1) The electrons in atoms are located in orbits, or energy levels, around the nucleus.
   (2) The electrons in orbits closest to the nucleus are of lower energy than those in orbits farther away from the nucleus.
   (3) Every electron in an atom may have only certain allowed energies. This energy determines what orbit the electron occupies.
   (4) Electrons can move from one orbit to another. To do this, an electron must gain or lose a certain amount of energy, a quantum of energy.

Name ______________________

MODULE A1 - 6 EXAMINATION

1. What is the ground state and the excited state?

2. In question number 1, what happens to move something from one to the other?

3. How can you account for the many lines in the hydrogen spectrum?

4. What is the maximum number of electrons permitted in the n = 3 energy level?

5. What is the meaning of 4f?

6. How many electrons are there in the following configurations:

   a. $2s^2 2p^6$

   b. $4s^2 3d^{10} 4p^1$

7. What is the relationship between the Periodic Table and electron configuration?

MODULE A1 - 6 EXAMINATION SOLUTION SET

1. The ground state is the state in which electrons are in the lowest energy levels available to them, that is, the lowest energy state of an atom. The excited state is an energy level of greater energy than the ground state.

2. If an electron receives energy from an outside source it moves from the ground state to an excited state.

3. The lines in the hydrogen spectrum are those which are characteristic of hydrogen. They are emitted under the proper test conditions and are a viable indication that hydrogen is present.

4. According to the Pauli exclusion principle, $2n^2$. In this case $n=3$; therefore, 18 electrons is the maximum number.

5. 4 is the principle quantum number and f is the subshell or suborbital.

6. a. 8

   b. 13

7. Each successive element in the Periodic Table has one additional electron. Those elements having eight electrons in their outer shell occupy the extreme right hand side of the table and are known as the inert gases.

Name ______________________

MODULE A1 - 7 EXAMINATION

1. Describe Rutherford's experiment and explain the results and the conclusions based upon the results.

2. State the basic postulates of the Bohr theory of atomic structure.

3. What is meant by the Pauli exclusion principle?

4. Illustrate the shapes of s and p orbitals and explain why the spatial arrangements are important.

5. Explain the meaning of polar molecules and give at least one example.

6. What is meant by the statement "Electrons can have opposite spin"?

7. Discuss the contributions of Balmer, Rydberg and Einstein to our knowledge of the structure of the atom.

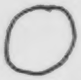
MODULE A1 - 7 EXAMINATION SOLUTION S

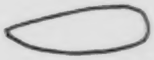
1. Rutherford used helium instead of hydrogen in an electric-discharge tube. The experiment generated positive rays consisting of helium ions and proved the existence of the nucleus.

2. Bohr's four postulates were:

   (1) The electrons in atoms are located in orbits, or energy levels, around the nucleus.
   (2) The electrons in orbits closest to the nucleus are of lower energy than those in orbits farther away from the nucleus.
   (3) Every electron in an atom may have only certain allowed energies. This energy determines what orbit the electron occupies.
   (4) Electrons can move from one orbit to another. To do this, an electron must gain or lose a certain amount of energy, a quantum of energy.

3. The Pauli exclusion principle states that no two electrons in a given atom can have the same set of quantum numbers.

4. 
S ORBITAL


P ORBITAL

The spatial orientations of the atomic orbitals are important because this orientation gives a molecule its shape, and shape plays an important role in determining the molecule's chemical and physical properties.

5. See Module A1-1 #5 examination solution set.

6. Two electrons in the same orbital spin in opposite directions.

7. Balmer's investigation attempted to determine whether there was a relationship between the lines in the visible spectrum produced by hydrogen gas and the wavelengths of those lines. His formula predicts what the wavelengths of the various lines should be.

$$\lambda = \frac{m^2}{m^2 - \text{A POSITIVE INTEGER}}$$

Rydberg derived the Rydberg constant (109,678) and an empirical formula for the relationship between hydrogen and its spectral lines. This formula would provide the lines in all series not just those for hydrogen.

Einstein formulated the equation $E = mc^2$. This means that energy, E, is equivalent to mass, m, times the velocity of light squared, c^2.

Name ______________________

MODULE A1 - 8 EXAMINATION

1. Give the electron designation for $_{18}$Argon:

2. Write a short description about five of the following people telling how they contributed to our understanding of the electron structure of the atom:

a. Balmer
b. Rydberg
c. Bohr
d. Thomson
e. Rutherford
f. Planck
g. Einstein

3. Define each of the following:

a. sigma bond

b. pi bond

c. $2p^5$

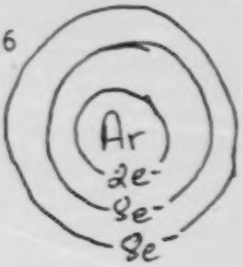
d. electron configuration

e. quantum numbers

f. polar molecule

MODULE A1 - 8 EXAMINATION SOLUTION SET

1. $1s^2 2s^2 2p^6 3s^2 3p^6$



2. See Module A1 - 1 #1 examination solution set.

3. a. Sigma bonds are bonds which are completely symmetrical.

   b. Pi bonds are bonds which are not symmetrical.

   c.
   $2p^5$ ← 5 electrons
   ↑ ↖ p subshell
   principle quantum number

   d. The electron configuration of an element describes the element's quantum numbers, the number of electrons at each principle quantum number as well as the electrons at specific energy sublevels.

   e. The principle quantum number is the number used to designate the principle energy levels that an electron may occupy in an atom.

   f. See Module A1 - 1 #5 examination solution set.

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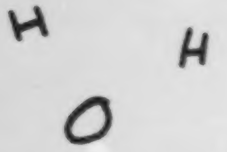
Name ______________________

MODULE A1 - 9 EXAMINATION

1. Discuss the meaning of the following figure:



2. Is there a relationship between electron configuration and the Periodic Table and if so, describe it:

3. What is the relationship between a quantum of energy and an energy state?

4. Define:

   a. spin quantum number

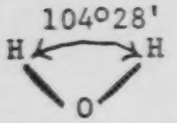
   b. principle quantum number

   c. hybrid bond

5. What is meant by the statement, "Each element has its own unique spectrum"?

6. How are Planck and Thomson related to our understanding of the electron configuration of atoms?

MODULE A1 - 9 EXAMINATION SOLUTION SET

1. 

The electrons H's in a water molecule unite with two p orbitals of the oxygen molecule forming s-p bonds. The positive charges of the H nuclei repel each other and force the orbital to the bond angle shown above. This allows H_2O molecules to arrange themselves in chains and lattices to form snow and ice crystals of great symmetry. This dipolar nature explains H_2O's high boiling point and solvent properties.

2. The electron configuration of an element describes the element's quantum numbers, the number of electrons at each principle quantum number as well as the electrons at specific energy sublevels.

   Also, the electron configuration determines an element's location in the Periodic Table.

3. The number of quanta of energy possessed by an electron determines the quantum level of the electron. An electron is moved from one energy level to the next higher level when it receives a quantum of external energy.

4. a. The spin quantum number describes the spin orientation of the electron.

   b. The principle quantum number is the number used to designate the principle energy levels that an electron may occupy in an atom.

   c. A hybrid bond is a bond, in a carbon compound, between sp^3 orbitals of carbon and s orbitals of hydrogen.

5. When evaluated under the correct experimental conditions, an element will emit a spectrum of light. The frequencies of light emitted by a given element are characteristic of that element.

6. Thomson derived a model of the atom which was called the raisen bread model. He also calculated the charge to mass ratio of an electron.

   Planck (and Einstein) introduced the concept of the quantum which states that light energy is available only in multiples of a basic unit of energy called a quantum. They also stated that a quantum of energy was related to the frequency of light.

Name ______________________

MODULE A1 - 10 EXAMINATION

1. The union of Thomson's and Millikan's work leads to the fact that the mass of an electron is 9.11×10^{-28} grams. What contribution did Thomson make to this knowledge?

2. According to Pauli, no two electrons in a given atom can have the same set of quantum numbers. What does this mean?

3. How do electrons get from one energy state to another?

4. What are Bohr's postulates and how do they help us to understand the electron configuration of atoms?

5. Describe each of the following:
   a. sigma bond
   b. pi bond
   c. hybrid bond

6. What is a dipolar molecule and what is the dipole moment?

MODULE A1 - 10 EXAMINATION SOLUTION SET

1. Thomson derived a model of the atom which was called the raisen bread model. He also calculated the charge to mass ratio of an electron.

2. This means that no matter where electrons are found in an atom all of their quantum numbers cannot be the same. Even if electrons are at the same energy sublevel, their quantum numbers differ. They have different spin quantum numbers.

3. Electrons move from a lower to a higher energy state when they receive a quantum of external energy.

4. Bohr's four postulates were:

   (1) The electrons in atoms are located in orbits, or energy levels, around the nucleus.
   (2) The electrons in orbits closest to the nucleus are of lower energy than those in orbits farther away from the nucleus.
   (3) Every electron in an atom may have only certain allowed energies. This energy determines what orbit the electron occupies.
   (4) Electrons can move from one orbit to another. To do this, an electron must gain or lose a certain amount of energy, a quantum of energy.

5. a. Sigma bonds are bonds which are completely symmetrical.

   b. Pi bonds are bonds which are not symmetrical.

   c. A hybrid bond is a bond, in a carbon compound, between sp^3 orbitals of carbon and s orbitals of hydrogen.

6. See Module A1 - 1 #5 examination solution set. The dipole moment is the measure of the extent of charge separation in a polar molecule.

ORGANIC CHEMISTRY

Organic Chemistry is an elective module. As a result of studying the organic chemistry module the student will be able to demonstrate the following competencies. He or she will be able to define and discuss the stability, solubility, conduction of heat and electricity and the physical properties of organic compounds; explain the characteristics of carbon in terms of covalent bonding, chaining and tetrahedral structure; illustrate saturated and unsaturated compounds; draw and discuss the benzine ring; describe and draw the alkane, alkene, and alkyne series; and identify halogen substitution products, alcohols, aldehydes, ketones, ethers, acids, esters, and amines.

Organic chemistry is the study of the compounds of carbon. There are nearly two million different carbon compounds that have been studied and described with thousands of new ones being reported every year. Although there are 103 elements, the total number of compounds of all these elements is far fewer than the number of compounds of carbon. The name "organic" is a relic of the past, when chemical compounds produced from once-living matter were called "organic" and all other compounds were called "inorganic".

Advance your slide carrousel to slide number one. Organic compounds tend to be soft solids, low boiling liquids or gases. Parafin, alcohol and propane are common organic compounds.

The slide pictures a small propane burner, parafin, and a bottle of ethyl denatured anhydrous alcohol.

SLIDE #1

Look at slide number two. Organic compounds are easily decomposed by heat. Paper chars very easily as do most organic solids.

The slide pictures several pieces of paper with charred edges.

SLIDE #2

Look at slide number three. Organic compounds are usually non-conductors of heat and electricity. This property makes them useful for such applications as insulation around electrical wires and for making clothes.

The slide shows a large spool of wire.

SLIDE #3

Advance to slide number four. The solubility of organic compounds depends upon the nature of the solvent used. Very few are soluble in water. Generally, they tend to dissolve in other organic materials that are in the liquid state. For example, oil will easily dissolve in gasoline. Also, the reaction rates of organic compounds generally is low when compared to inorganic compounds.

Look at slide number five. The properties or organic materials are due in large measure to the unusual properties of carbon. Carbon forms four covalent bonds and these bonds are at very definite angles to one another. The angle between bonds tends to be 109 degrees 28 minutes. The black ball in slide five represents carbon, and the sticks, its bonds. The carbon atom can be thought of as being in the center of a regular tetrahedron and its bonds pointing to the vertices of the tetrahedron. (You will recall that this phenomenon was discussed in Module A1.)

Now look at slide number six. Carbon atoms have the ability to produce long chains by forming covalent bonds with other carbon atoms. The ability of

The slide shows a 250ml beaker filled half with water and half with light oil. There is a good interface between the liquids.

SLIDE #4

This slide pictures a ball and stick model of carbon showing the carbon bond angles.

SLIDE #5

The slide shows two ball and stick models of carbon molecules. One molecule is benzene and the second is C_4H_{10}.

SLIDE #6

carbon atoms to form rings and chains accounts for the large number of possible compounds.

Obtain a ball and stick model kit. Take 4 black balls to represent carbon atoms and some sticks with which to put them together. You should be able to find two possible arrangements.

Look at slide number seven. You should have been able to find two different ways of connecting the atoms. Differing structural forms having the same identical number of atoms are called isomers. Isomers, although identical in numbers of atoms, have different physical and chemical properties. As the number of carbon atoms per molecule increases, the number of possible isomers increases tremendously. Take 6 carbon atoms from your kit and connect them in a ring. The ring will not lie flat. There are two possible ways that the ring can be constructed. Try constructing such a ring.

The slide shows two ball and stick models of C_4H_{10}. One is an isomer.

SLIDE #7

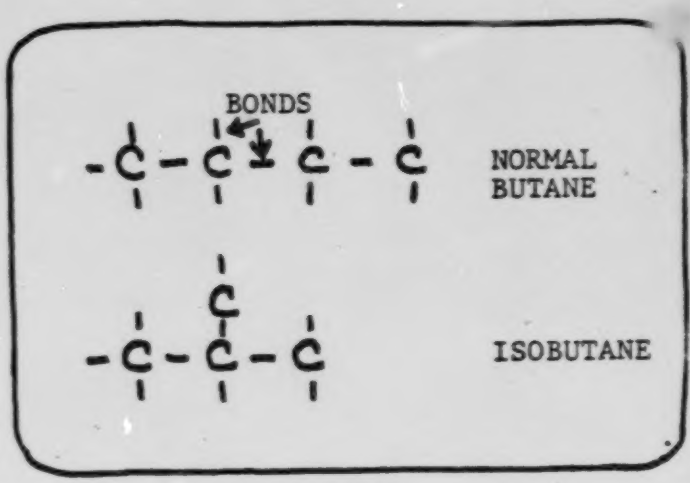
Advance to slide number eight. Were you able to obtain two forms? This type of isomerism is called cis-trans isomerism, and is quite common in more complex molecules. In many cases it gives the molecules a left and right handedness. Cis-trans isomers differ in physical and chemical properties.

The slide shows two ball and stick models of carbon ring molecules showing cis-trans isomerization. (Six carbon atoms in the ring.)

SLIDE #8

The ability of carbon to bond to itself and isomerism makes possible the million-plus organic compounds that exist.

Look at slide number nine. There is a simple way of showing structure in organic compounds. Let the symbol represent the atom and dashes represent the bonds. The two isomers from slide number seven are represented on this slide. All isomers cannot be shown this way because we are limited to two dimensions. For example, the isomer of the cycloheptane shown in slide number eight cannot be represented.



SLIDE #9

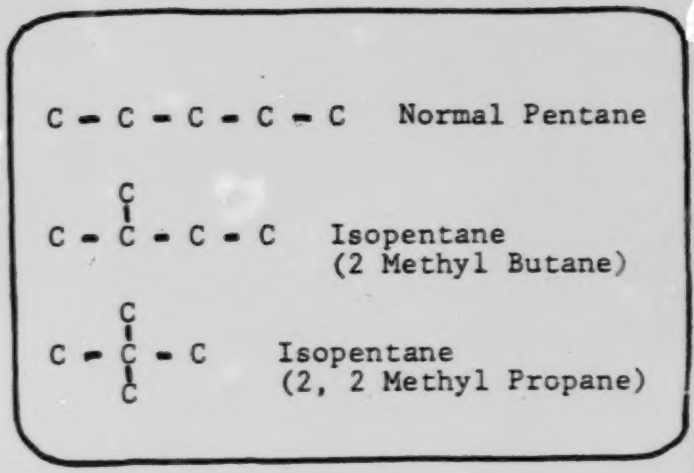
Look at slide number ten. Using structural formulas try to draw the possible isomers of pentane, C_5H_{12}.

C_5H_{12}

SLIDE #10

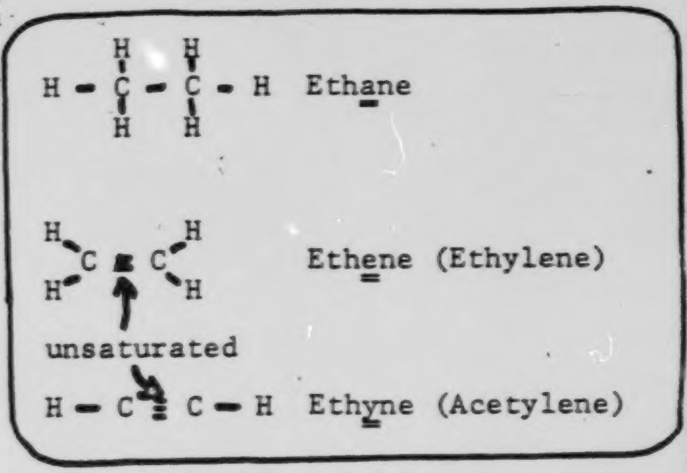
Show only those bonds which are between the carbon atoms. The ball and stick models may be a useful aid.

Now advance to slide number eleven. Here the isomers are drawn fr you. The names are attached as a matter of curiosity. We will return to that problem later.


Normal Pentane
Isopentane
(2 Methyl Butane)
Isopentane
(2, 2 Methyl Propane)

SLIDE #11

Look at slide number twelve. It is possible for carbon to form more than one bond with another carbon atom. Compounds in which carbon atoms share more than one pair of electrons between them are called UNSATURATED compounds. Those compounds in which carbon atoms share only one bond are called saturated.


Ethane
Ethene (Ethylene)
unsaturated
Ethyne (Acetylene)

SLIDE #12

The names of the three compounds are included. The international names are listed first with the common names in brackets. Ethylene is the material from which polyethylene is made. Acetylene you have used in cutting torches.

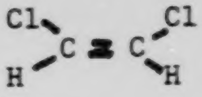
To get a better idea of these molecules, build them with the ball and stick kits. Use springs for the double bonds between carbon atoms and sticks for the other bonds. Place the yellow balls, which represent hydrogen, on the sticks. This should give you a fairly good picture of the molecules.

The slide shows three ball and stick models showing carbon to carbon single, couble, and trible bonds.

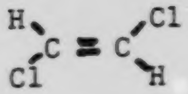
SLIDE #13

Look at slide number thirteen. The models are built there for you to compare with yours. Take your model of ethylene and try to twist it in the middle. Notice that it cannot be twisted without destroying bonds. This gives rise to the possibility of more isomers.

Now advance to slide number fourteen. Here you will find two isomers of ethylene.



CIS FORM



TRANS FORM

SLIDE #14

Look at slide number fifteen. As a result of studying this section you should know the definition of organic compounds and their general properties. You should also be able to name the kind of bonding and draw a model of carbon with its bonds. Finally, you should be able to use and interpret structural formulas and be able to define or identify saturated compounds, unsaturated compounds and isomerism.

DEFINITION OF ORGANIC

GENERAL PROPERTIES OF ORGANICS

BONDING: TYPE
SPECIFICS OF CARBON

STRUCTURAL FORMULAS

ISOMERS

SATURATED - UNSATURATED

SLIDE #15

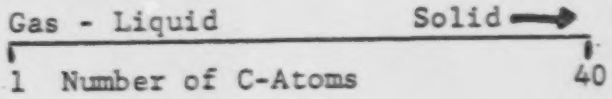
Advance to slide number sixteen. Let us look at some classes of organic compounds. These classes of organic compounds may be recognized from the numbers and arrangements of certain atoms or groups of atoms in their structural formulas. The simplist class is the hydrocarbons. Hydrocarbons contain only carbon and hydrogen. They may be in the form of straight chains, branched chains, or rings, and may contain from one to forty carbon atoms. They may be gases, liquids with a low boiling point, or solids with a low melting point.

See Page 350A - Following

SLIDE #16

As the number of carbons increases, the tendency is to move from gases to solids.

Look at slide number seventeen. The relationship between increasing numbers of carbons and the state of the compound are indicated on the graph.



SLIDE #17

WITH PLENTY OF AIR:

$C_3H_8 + 5O_2 \longrightarrow 4H_2O + 3CO_2$

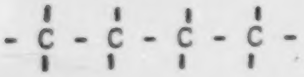
WITH SHORT SUPPLY OF AIR:

$C_3H_8 + 7/2O_2 \longrightarrow 4H_2O + 3CO$

SLIDE #18

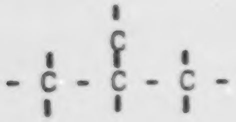
Now advance to slide number eighteen. The nonpolar nature of hydrocarbon molecules makes them quite insoluble in water. They burn, however, to form carbon dioxide, carbon

HYDROCARBONS



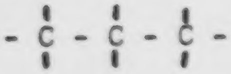
$-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$

Aliphatic, Straight Chain
Saturated



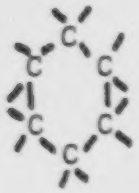
$-\overset{|}{\underset{|}{C}}-\overset{\overset{|}{C}}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$

Aliphatic, Branched Chain
Saturated

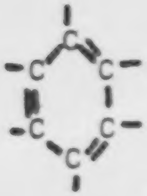


$-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$

Aliphatic, Straight Chain
Unsaturated



Aliphatic, Ring
Saturated



Aromatic, Ring
Unsaturated

SLIDE #16

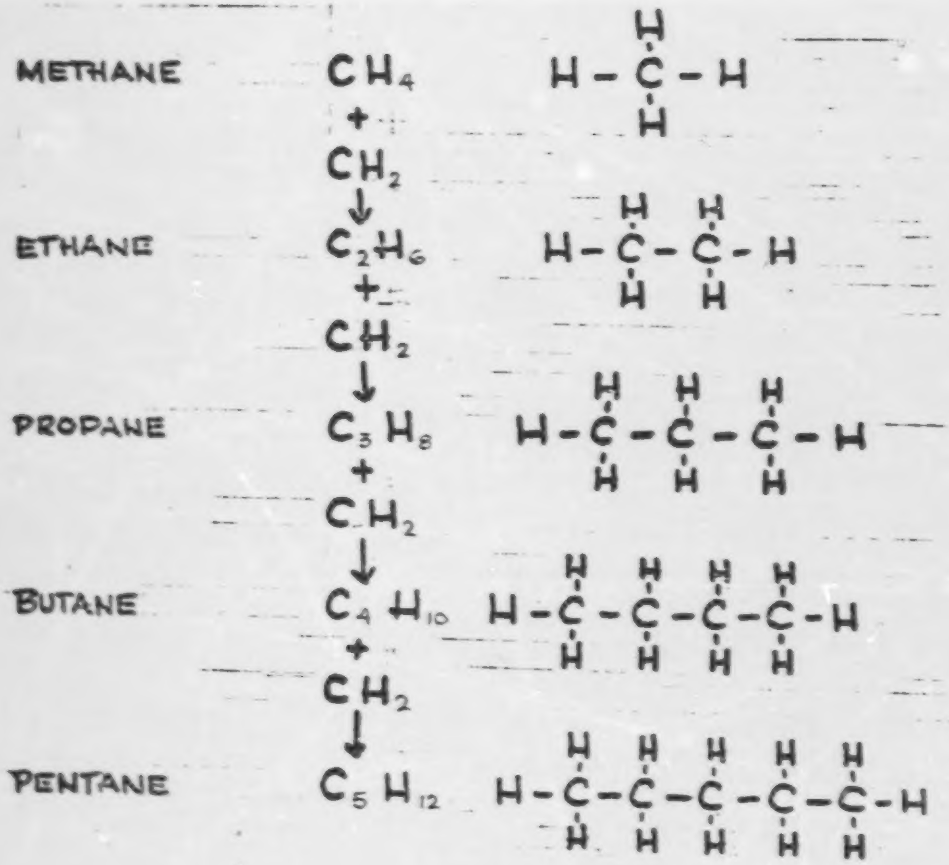
monoxide, and water vapor. Carbon monoxide forms when there is a shortage of oxygen. Burners should be adjusted to minimize the production of CO but still maintain a high flame temperature.

Look at slide number nineteen. Organic compounds can be classified into groups having related structures. Such groups are called homologous series. Each consecutive member of an homologous series differs from the one before it by a common increment. The increment in the alkane series is CH_2. The next one in the series is hexane, then heptane, then octane, and so on, using the latin number prefixes with the ending "ane".

See Page 351A - Following

SLIDE #19

Alkanes have a general formula C_nH_{2n+2}. They are saturated since only single bonds exist between adjacent carbon atoms. (This is also indicated by the word ending "ane".) The naming of this series is the basis of the systematic way of naming organic compounds.



METHANE CH_4 $H-\overset{H}{\underset{H}{C}}-H$

$+$

CH_2

$\downarrow$

ETHANE C_2H_6 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$

$+$

CH_2

$\downarrow$

PROPANE C_3H_8 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$

$+$

CH_2

$\downarrow$

BUTANE C_4H_{10} $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$

$+$

CH_2

$\downarrow$

PENTANE C_5H_{12} $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$

Advance to slide number twenty. There are several homologous series of unsaturated hydrocarbons. You will recall that unsaturated hydrocarbons have double or triple bonds between adjacent hydrocarbons. The alkene series begins with ethene which corresponds to ethane in the alkane series.

The slide shows two ball and stick models showing carbon to carbon double and triple bonds.

SLIDE #20

Look at slide number twenty-one. The three series are listed here for comparison. Note that there can be no anolog for methane since there can be no multiple bonds between carbon atoms.

The names of the three series can be distinguished by the name endings -ane, -ene, and -yne. Once you know the alkane series, the other names are easily determined.

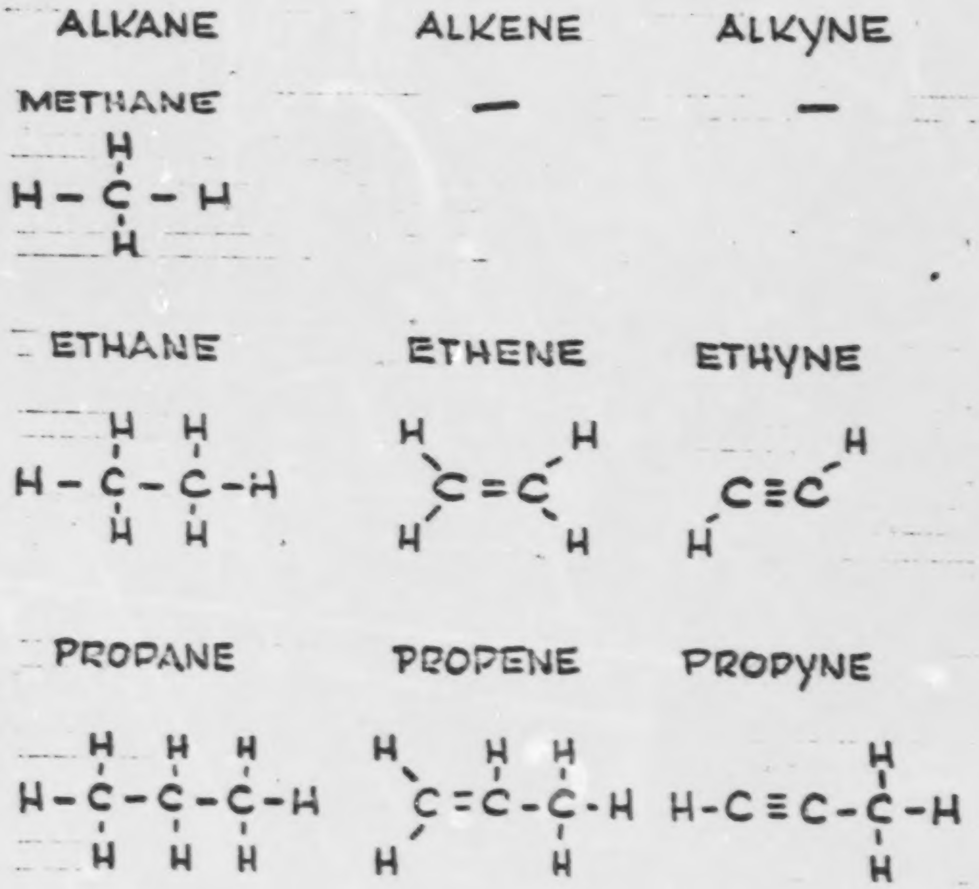
See Page 352A - Following

SLIDE #21

Look at slide number twenty-two. The only unsaturated cyclic hydrocarbon we will consider is benzene. It is double bonded in alternate fashion as can be seen on the slide. Benzene is the material from which many other materials are made.

The slide shows a ball and stick model of the benzene ring structure.

SLIDE #22


ALKANE
ALKENE
ALKYNE
METHANE
—
—
ETHANE
ETHENE
ETHYNE
PROPANE
PROPENE
PROPYNE

SLIDE #21

Advance to slide number twenty-three. Phenolic plastics, explosives, dyes, and solvents are but a few materials made from organic compounds.

See Page 353A - Following

SLIDE #23

Look at slide number twenty-four. In some homologous series of organic compounds one or more hydrogens of a hydrocarbon may be replaced by other elements. Organic compounds often can be considered as being composed of one or more functional groups attached to a hydrocarbon molecule.

A functional group is a particular arrangement of a few atoms which gives characteristic properties to an organic molecule. Each of the functional groups on slide number twenty-four gives rise to a class of compounds with similar chemical characteristics.

See Page 353B - Following

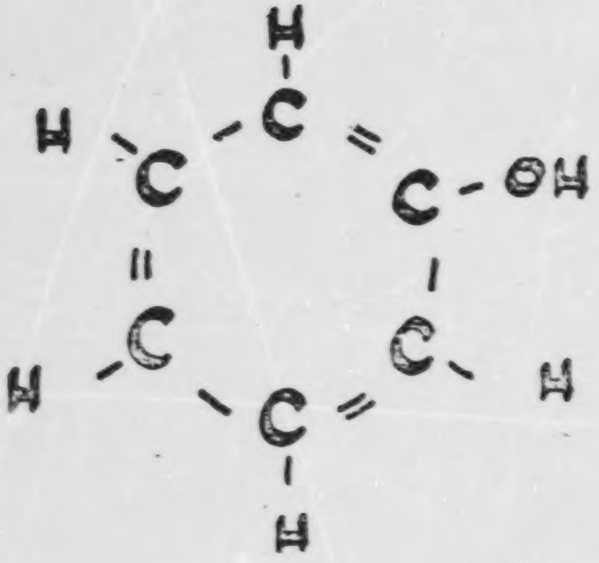
SLIDE #24

Organic compounds are usually named from their corresponding hydrocarbons but are not necessarily prepared from that hydrocarbon.

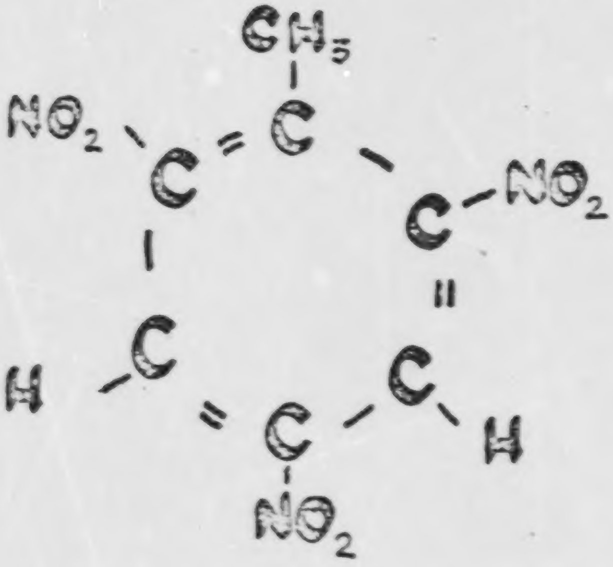
Look at slide number twenty-five. The simplist alcohol is methanol. The one carbon indicates methane and the OH determines the OL ending. Sometimes it is called methyl alcohol;

See Page 353C - Following

SLIDE #25



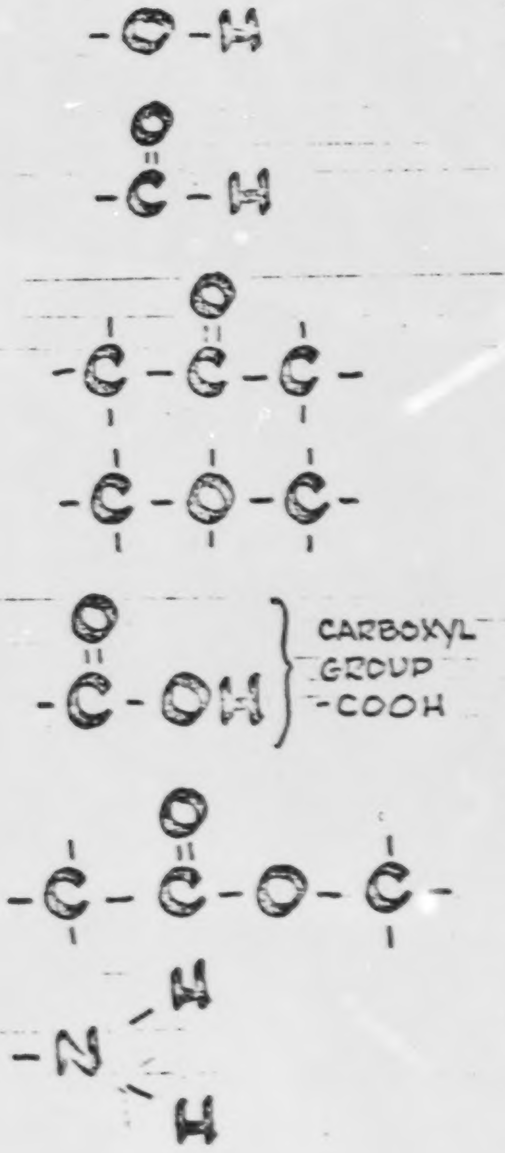
PHENOL



TRINITRO-
TOLUENE-TNT

SLIDE #23

FUNCTIONAL GROUPS



ALCOHOL $-O-H$

ALDEHYDE $-\overset{O}{\overset{\|}{C}}-H$

KEYTONE $-\overset{|}{\underset{|}{C}}-\overset{O}{\overset{\|}{C}}-\overset{|}{\underset{|}{C}}-$

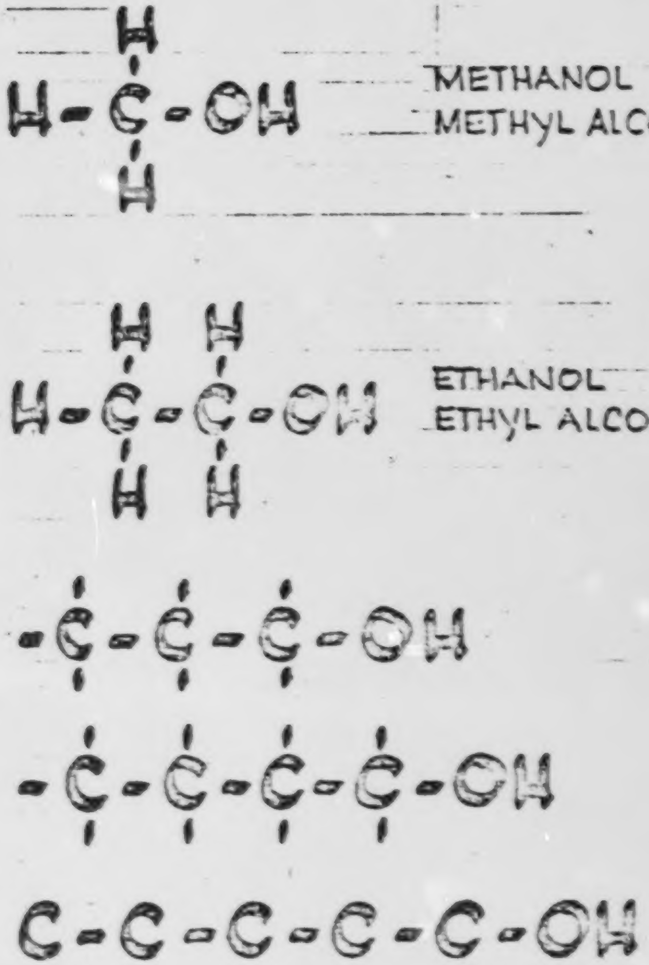
ETHER $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{O}}-\overset{|}{\underset{|}{C}}-$

ACID $-\overset{O}{\overset{\|}{C}}-OH$ } CARBOXYL GROUP $-COOH$

ESTER $-\overset{|}{\underset{|}{C}}-\overset{O}{\overset{\|}{C}}-O-\overset{|}{\underset{|}{C}}-$

AMINE $-N\genfrac{}{}{0pt}{}{/H}{\backslash H}$

SLIDE #24



$$\begin{array}{c} H \\ | \\ H-C-OH \\ | \\ H \end{array}$$

METHANOL
METHYL ALCOHOL

$$\begin{array}{c} H\ \ H \\ |\ \ \ | \\ H-C-C-OH \\ |\ \ \ | \\ H\ \ H \end{array}$$

ETHANOL
ETHYL ALCOHOL

$$\begin{array}{c} |\ \ \ |\ \ \ | \\ -C-C-C-OH \\ |\ \ \ |\ \ \ | \end{array}$$

$$\begin{array}{c} |\ \ \ |\ \ \ |\ \ \ | \\ -C-C-C-C-OH \\ |\ \ \ |\ \ \ |\ \ \ | \end{array}$$

C-C-C-C-C-OH

SLIDE #25

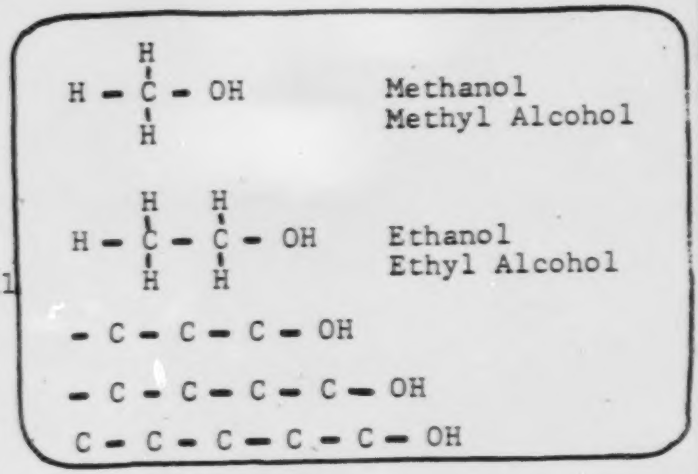
however, its common name is wood alcohol. The second one is ethanol, or ethyl alcohol, which is called grain alcohol. You name the third, fourth, and fifth alcohols listed there.

They are proponol, butanol, and pentanol; or propyl alcohol, butyl alcohol, and pentyl alcohol.

Obtain a sample set of organic liquids and bring it to your carrel. All that you will do with the samples is look at them and smell them. Most, but not all, are toxic. Most form explosive mixtures in the air. Being able to recognize them might at some time be valuable aboard ship.

Since the alcohols have the same functional group, namely OH, they have similar properties. Similar properties means similar odors since odor is the chemical effect of substances on the nervous system. Smell the samples of alcohol and note the similarity between them. If you need some contrast, smell one of the aldehydes.

Look at slide number twenty-six. Here is some additional information about alcohols. Methanol, that is, wood alcohol, is a deadly poison. It cannot be made drinkable by any physical process including straining it through bread or a sock. Some common sources of wood alcohol are cheap antifreeze, and sterno cans. It causes extensive liver damage, irreversable blindness, and death if taken in quantity.



SLIDE #26

Ethyl alcohol or grain alcohol, when diluted, is potable. It is the active ingredient in any kind of alcoholic beverage. If affects the nervous system, as you may well know, imparing reactions and inhabitions. Very large quantities, such as chug-a-lugging a bottle of vodka, can cause death. Prolonged excessive use can cause liver and brain damage.

Pure ethyl alcohol is a powerful dehydrating agent. A live worm dropped into 100% alcohol dehydrates to almost nothing in a few minutes. It will do the same thing to your stomach.

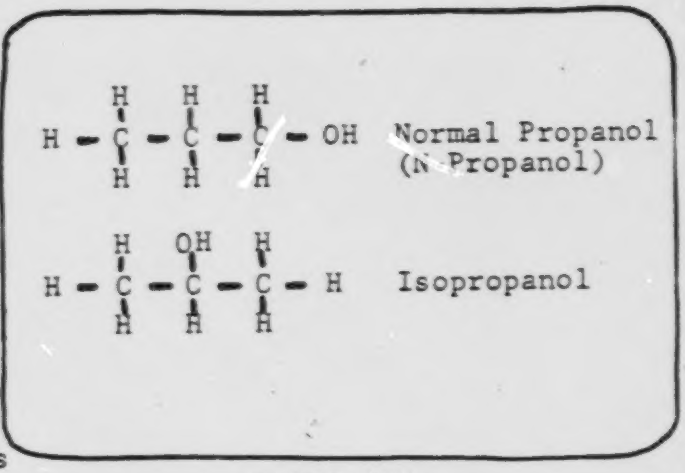
The slide shows a bottle of 100 proof Smirnoff vodka.

SLIDE #27

Advance to slide number twenty-seven. Ethanol concentrations are sometimes measured by a system called "proof". The "proof" of an ethanol solution is double the percentage. Then, 100% alcohol is 200 proof, 100 proof vodka is 50% alcohol, and 86 proof rye is 43% alcohol. Solutions above 100 proof are flammable. Alcohol burns with a relatively cool flame, and forms explosive mixtures with air if in high concentrations.

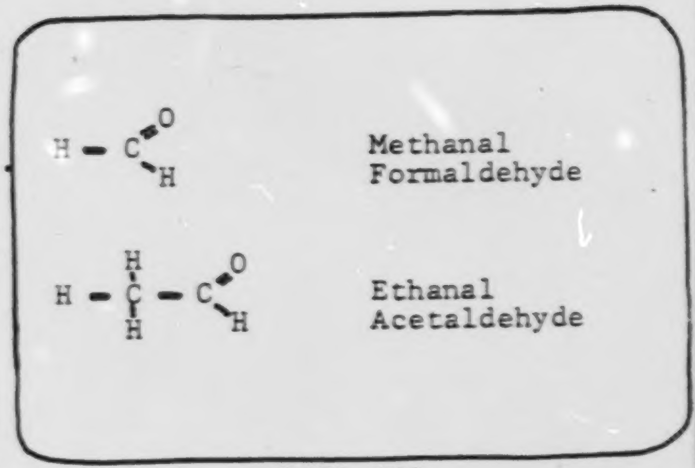
Ethyl and methyl alcohols are used for industrial solvents. They are frequently a step in making synthetics.

Look at slide number twenty-eight. Starting with proply alcohol, isomers are possible. Isopropyl alcohol is ordinary rubbing alcohol and is not potable. Only ethanol is potable.



SLIDE #28

Look at slide number twenty-nine. Aldehydes contain a CHO group. Their names are derived from the corresponding alkane and ending AL is added. They have a pungent odor which is easily recognized.



SLIDE #29

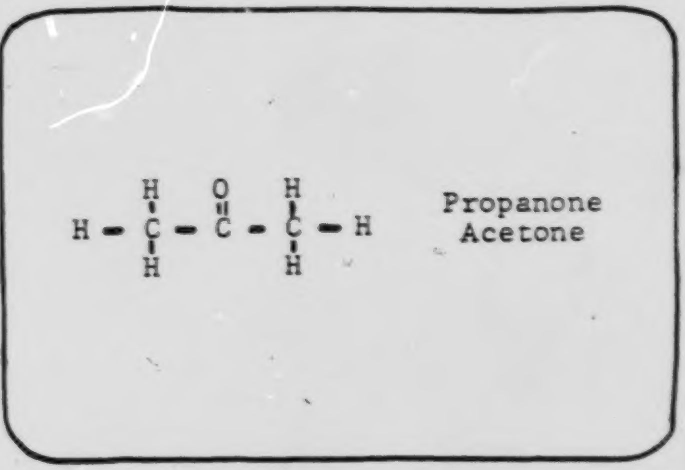
Look at slide number thirty. The most common aldehyde is formaldehyde which is used as a preservative. You have probably come across it in biological studies. Large quantities of it

The slide shows a formaldehyde and a piece of plastic.

SLIDE #30

are used in making plastics. Bakelite, a plastic commonly used for such things as pot handles, insulators, and knobs for radios, is made from phenol and formaldehyde.

Look at slide number thirty-one. Ketones have a peculiar odor that is recognizable. The most common ketone is acetone. It is a widely used industrial solvent.

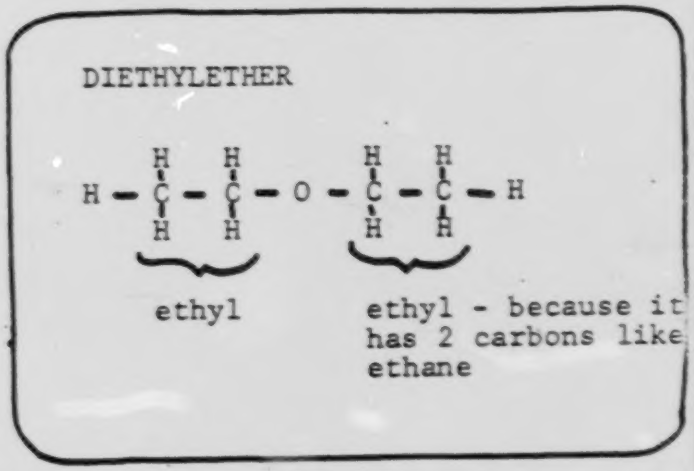


$$H-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{H}{C}}-H$$

Propanone
Acetone

SLIDE #31

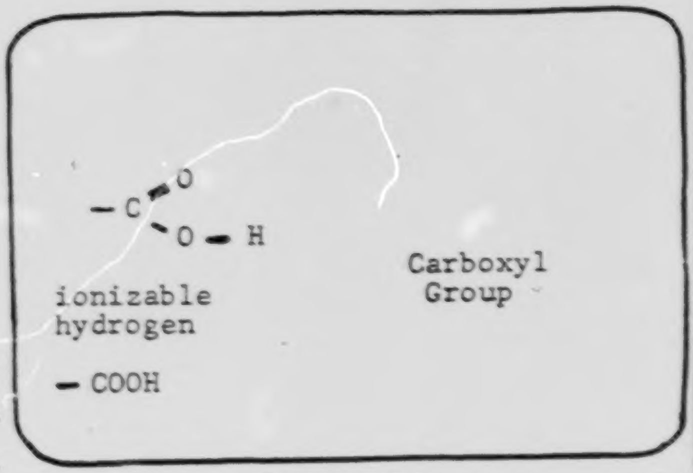
Look at slide number thirty-two. An ether group has an oxygen as part of the carbon chain. Low molecular weight ethers are volatile and easily form explosive mixtures with the air. The diethyl ether on slide number thirty-two is used as an anesthetic.



DIETHYLETHER

$$H-\underbrace{\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}}_{\text{ethyl}}-O-\underbrace{\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}}_{\text{ethyl - because it has 2 carbons like ethane}}-H$$

SLIDE #32



$$-C\begin{matrix}=O\\ -O-H\end{matrix}$$

ionizable hydrogen

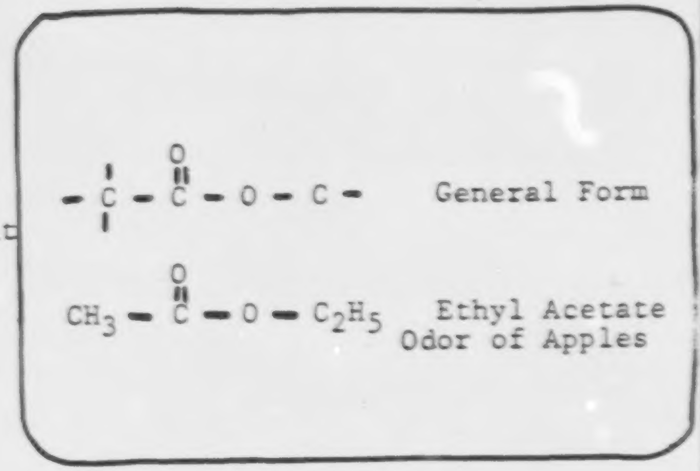
Carboxyl Group

$-COOH$

SLIDE #33

Look at slide number thirty-three. Organic acids are characterized by a functional group called a carboxyl group. The hydrogen attached to the oxygen is ionizable, making the group an acid. Methanoic acid or formic acid, is the active ingredient in bee stings. Acetic acid or ethanoic acid, when diluted, is vinegar. Acetic acid is often the starting point for making other chemicals and plastics, such as rayon acetate. Notice the sour smell of the acetic acid.

Look at slide number thirty-four. Esters generally have the odor of fruit or mint. They are responsible for much of what we can smell or taste. Esters are often used in synthetic flavorings.

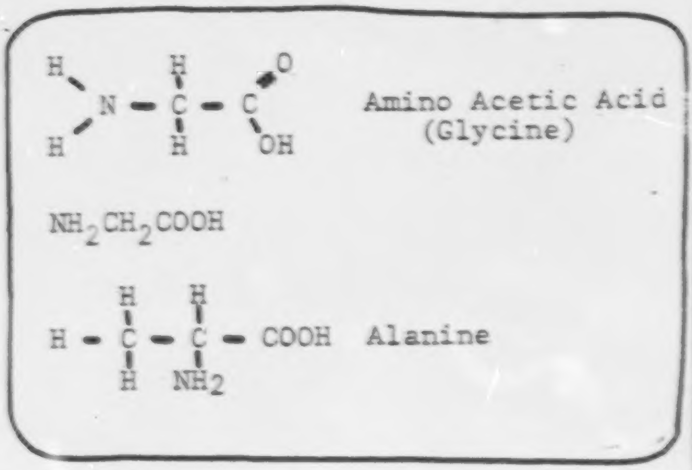


$-\underset{|}{\overset{|}{C}}-\overset{O}{\overset{\|}{C}}-O-C-$ General Form

$CH_3-\overset{O}{\overset{\|}{C}}-O-C_2H_5$ Ethyl Acetate
Odor of Apples

SLIDE #34

Look at slide number thirty-five. Amines have a characteristic NH_2 group. They are crutial biologically. When this group is attached to an organic acid it forms the building blocks of proteins essential to life.



Amino Acetic Acid
(Glycine)

NH_2CH_2COOH

$H-\underset{H}{\overset{H}{C}}-\underset{NH_2}{\overset{H}{C}}-COOH$ Alanine

SLIDE #35

Advance to slide number thirty-six. Nylon is an amine and an acid.

This slide pictures women's legs with nylon stockings on them.

SLIDE #36

Look at slides number thirty-seven and number thirty-eight.

As a result of studying this module, you should be able to (1) write equations for hydrocarbon combustion with excess and limited air supplies, (2) explain the relationship between the bonding of hydrocarbons and solubility and (3) explain the relationship between molecular weight and melting point.

For the homologous series you should be able to:

1. Write and recognize names and formulas for the first five alkanes.
2. Recognize the general structure of the alkene and alkyne series
3. Write and recognize the structure of benzene.
4. Identify uses for benzene.

For the functional groups you should be able to: Recognize simple members of each group and know a use for each. In addition, you should know the physiological effects of alcohols.

You should be able to: (1) write equations for hydrocarbon combustion; (2) explain the relationship between bonding and solubility; and (3) explain the relationship between molecular weight and melting point. For the homologous series you should be able to: (1) write and name first five alkanes; (2) general structure of alkene and alkyne series; (3) write and recognize the structure of benzene; and (4) identify uses for benzene.

SLIDE #37

For the functional groups you should be able to: (1) recognize simple members of each group; and (2) know a use for each.

Also, you should know the physiological effects of alcohols.

SLIDE #38

MODULE E-1 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the MODULE E-1 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE E-1 as well as to the completion of the problem set. Those pages are: 4, 35, 46, 48, 69, 72, 83, 186-188, 195-196, 200, 203, 206, 282-298.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown.

Page	Problems
300	1, 2, 3, 5, 7, 10

MODULE E-1 PROBLEM SET SOLUTIONS

Page Problem

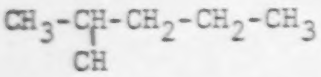
300 (1) $C_6H_5\text{-}O\text{-}CH_3$ is an ether

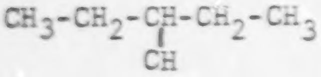
$C_2H_5B_r$ is a halide

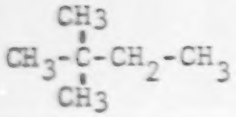
$CH_3CH_2CH_2NH_2$ is an amine

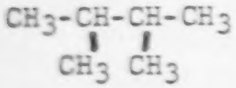
CH_3CO_2H is an acid

300 (2) $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}\ CH_2\text{-}CH_3$ n-hexane


$CH_3\text{-}\underset{CH}{\underset{|}{CH}}\text{-}CH_2\text{-}CH_2\text{-}CH_3$ 2-methylpentane


$CH_3\text{-}CH_2\text{-}\underset{CH}{\underset{|}{CH}}\text{-}CH_2\text{-}CH_3$ 3-methylpentane


$CH_3\text{-}\overset{CH_3}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}\text{-}CH_2\text{-}CH_3$ 2,2 dimethylbutane


$CH_3\text{-}\underset{CH_3}{\underset{|}{CH}}\text{-}\underset{CH_3}{\underset{|}{CH}}\text{-}CH_3$ 2,3 dimethylbutane

300 (3) a. $CH_3CH_2CH_2CHClCH_2CH_2CH_3$ 4-chloropheptane

b. $CH_3CH_2CH = CHCH_2CH_2CHBrCH_3$ 7-bromo -3-octene

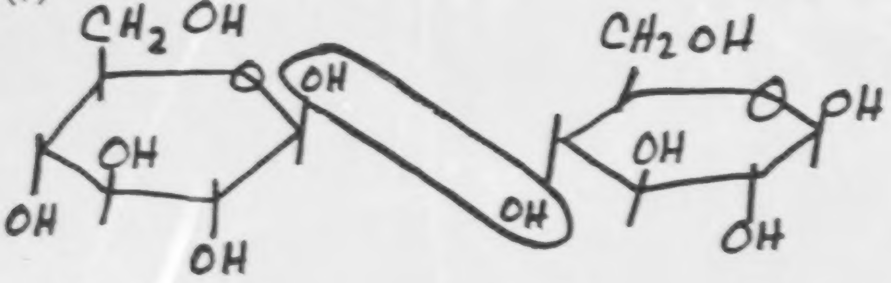
c. $CH_3CH_2C = CCH_3$ 2-pentyne

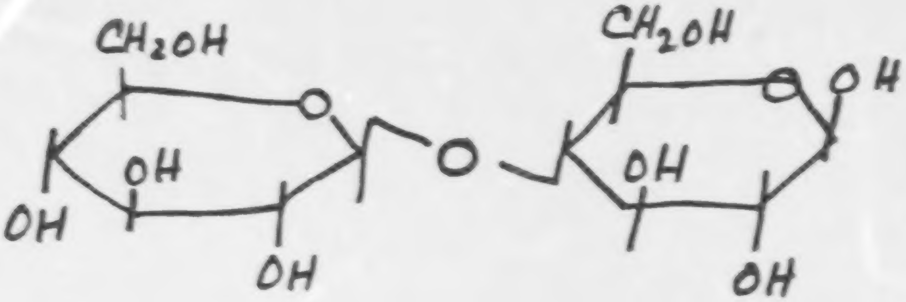
300 (5) $CH_3\text{-}CH_3Cl_2 \longrightarrow$

$CH_3\text{-}CH_2Cl$	1-chloroethane
$CH_3\text{-}CHCl_2$	1,1-dichloroethane
$CH_3\text{-}CCl_2$	1,1,1-trichloroethane
$CH_2Cl\text{-}CCl_3$	1,1,1,2-tetrachloroethane
$CHCl_2\text{-}CCl_3$	1,1,1,2,2-pentachloroethane
$CCl_3\text{-}CCl_3$	1,1,1,2,2,2 hexachloroethane
$CH_2Cl\text{-}CH_2Cl$	1,2-dichloroethane
$CHCl_2\text{-}CHCl_2$	1,1,2,2-tetrachloroethane

Page Problem

300 (7)





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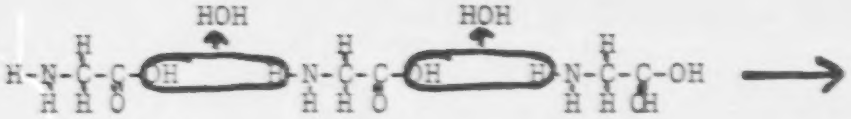

$$\mathrm{H{-}\underset{H}{N}{-}\overset{H}{\underset{H}{C}}{-}\underset{O}{C}{-}\boxed{OH \quad H}{-}\underset{H}{N}{-}\overset{H}{\underset{H}{C}}{-}\underset{O}{C}{-}\boxed{OH \quad H}{-}\underset{H}{N}{-}\overset{H}{\underset{H}{C}}{-}\underset{O}{C}{-}OH} \longrightarrow$$

$$\overset{HOH}{\uparrow} \qquad \overset{HOH}{\uparrow}$$

$H_2N\text{-}CH_2\text{-}CONH\text{-}CH_2\text{-}CO_2H + 2H_2O$

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Name ______________________________

MODULE E1 - 1 EXAMINATION

1. Define the following terms:

   a. covalent bonding

   b. tetrahedral structure

   c. isomer

2. Give an example of a single, double, and triple bond between two carbon atoms:

3. What is meant by organic compounds?

4. Give an example of an unsaturated compound (its formula):

5. What is the difference between an alkane and an alkene, an alkane and an alkyne, an alkene and an alkyne. That property which causes them to be differently named.

6. Draw a molecule whose formula is:

   a. CH_4

   b. CH_3CH_3

   c. CH_3OH

MODULE E1 - 1 EXAMINATION SOLUTION SET

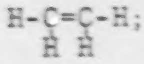
1. a. A covalent bond is one in which electrons are shared between atoms which make up a compound.

   b. When the carbon atom bonds it is thought of as being the center of a regular tetrahedron with its bonds pointing at or to the vertices of the tetrahedron.

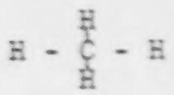
   c. Isomers are compounds with the same molecular formula but structural formulae.

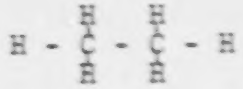
2. C-C; C=C; C≡C

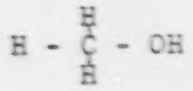
3. Organic compounds are compounds which contain carbon.

4. 
   $H-\underset{H}{C}=\underset{H}{C}-H$; C_2H_4

5. Alkanes have single bonded carbons; alkenes have doubly bonded carbons; and alkynes have three bonds between carbon atoms.

6. a. 
   $H-\overset{H}{\underset{H}{C}}-H$

   b. 
   $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$

   c. 
   $H-\overset{H}{\underset{H}{C}}-OH$

Name ______________________________

MODULE E1-2 EXAMINATION

1. What is organic chemistry?

2. Define the following in terms of their functional groups:
    a. alcohol
    b. acid
    c. ketone
    d. ether
    e. ester

3. What are the physiological effects of ethanol?

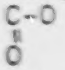
4. What is meant by 90 proof?

5. What types of carbon compounds are formed with the addition of NH_2 groups?

6. What is benzine and how does its structural formula appear?

MODULE E1 - 2 EXAMINATION SOLUTION SET

1. The chemistry of carbon compounds.

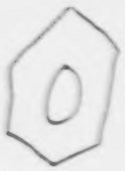
2. a. OH
   b. COOH
   c. C=O
   d. -O-; R-O-R
   e. 
   $\underset{\overset{\|}{O}}{C}-O$

3. Ethanol affects the nervous system, imparing reactions and inhabitions. The intake of very large quantities can cause death and prolonged excessive use can cause liver and brain damage.

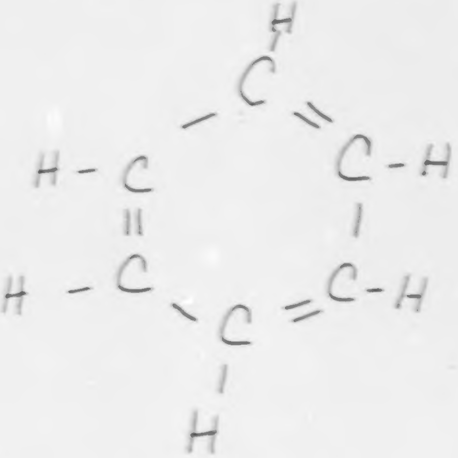
4. 90 proof means that the liquid is 45% alcohol.

5. Amines and amides.

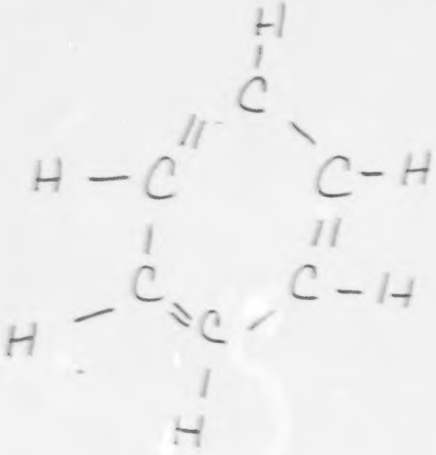
6. Benzene is an aromatic hydrocarbon



OR



OR



Name ______________________

MODULE E1 - 3 EXAMINATION

1. Name several characteristics of carbon to carbonding:

2. Draw and name the first five members of the alkane series:

3. Describe the physiological effects of methanol consumption:

4. Draw the functional groups of each of the following:
    a. aldehyde
    b. amine
    c. halogen

5. Illustrate cis-trans and structural isomerization:

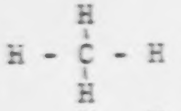
6. What is the relationship between organic compounds and heat and electricity conduction?

MODULE E1 - 3 EXAMINATION SOLUTION SET

1. Unsaturated carbon compounds can participate in addition reactions. Saturated hydrocarbons undergo substitution reactions. The ability to form isomers. The ability to form rings and chains.

2.

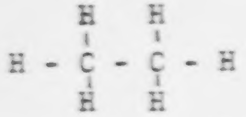
METHANE



$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$$

CH_4

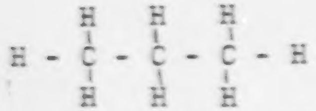
ETHANE



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

C_2H_6

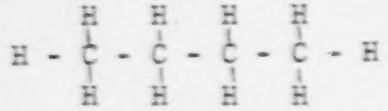
PROPANE



$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

C_3H_8

BUTANE



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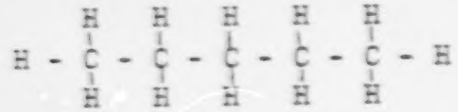
C_4H_{10}

PENTANE



$$\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & \end{array}$$

C_5H_{12}

3. Death

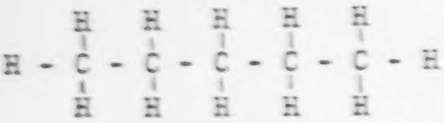
4. a. COH, C-H
   O

   b. NH_2; $R-NH_2$

   c. R-Cl; R-Br; R-I

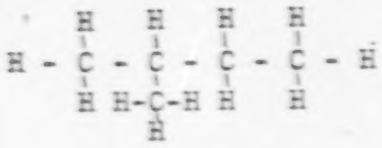
5. a. Structural isomerisn

C_5H_{12}



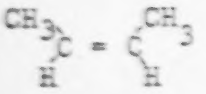
$$\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & \end{array}$$

h - pentane

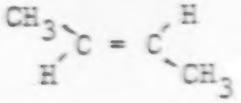


2 - methylbutane

b. cis-trans



cis-2-butane



trans-2-butane

6. Organic compounds are nonconductors of heat and electricity.

Name ______________________________

MODULE E1 - 4 EXAMINATION

1. What are organic compounds?

2. Discuss the solubility or organic compounds:

3. To what can you attribute the properties or organic materials?

4. What is the relationship between carbon bonds and the verticies of a tetrahedron?

5. Draw three isomers of C_5H_{12}:

6. What organic series has the general formula $C_nH_{2n}+2$ and what does the formula mean?

MODULE E1 - 4 EXAMINATION SOLUTION SET

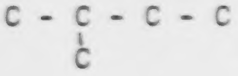
1. Compounds which contain carbon.

2. The solubility of carbon compounds depends upon the nature of the solvent used. Generally, they tend to dissolve in other organic compounds.

3. Carbon bonding.

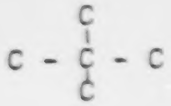
4. Carbon forms bonds such that the four bonds point to the four corners or verticies of a tetrahedron.

5.



$C - \underset{C}{\underset{|}{C}} - C - C$

C - C - C - C - C



$C - \overset{C}{\overset{|}{\underset{C}{\underset{|}{C}}}} - C$

6. The alkane series. The formula means that for every carbon atom in a compound, there are twice as many hydrogen atoms plus two hydrogen atoms.

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Name ______________________________

MODULE E1 - 5 EXAMINATION

1. You are walking down the street and you see a person stumble, fall, and mutter that it was a good drink. Then the person looses consciousness and soon the heart ceases to function. What might have been this persons problem?

2. What is a homologous series?

3. Give examples of ethane, ethene, ethanol, and ethanal:

4. Name the various functional groups, and write their general formulas:

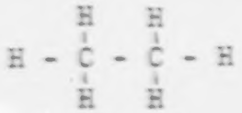
5. What is meant by structural isomerization? Give an example:

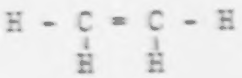
6. What are proteins and where are they found?

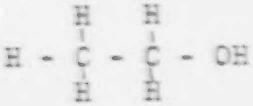
MODULE E1 - 5 EXAMINATION SOLUTION SET

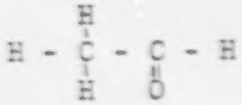
1. The person probably drank wood alcohol.

2. An homologous series is a series of compounds in which each memeber differs from the preceding member by one CH_2 unit.

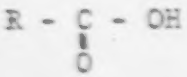
3. ETHANE 
$\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$

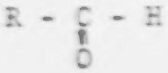
ETHENE 
$\mathrm{H-\underset{H}{C}=\underset{H}{C}-H}$

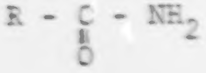
ETHANOL 
$\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH}$

ETHANOL 
$\mathrm{H-\overset{H}{\underset{H}{C}}-\underset{O}{\overset{}{C}}-H}$ (with $\mathrm{C=O}$)

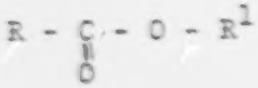
4. ALCOHOL R-OH

ACID 
$\mathrm{R-\underset{\|}{C}-OH}$, $\mathrm{\underset{O}{}}$ i.e. $\mathrm{R-C(=O)-OH}$

ALDEHYDE 
$\mathrm{R-C(=O)-H}$

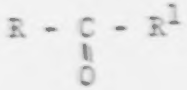
AMIDE 
$\mathrm{R-C(=O)-NH_2}$

AMINE $\mathrm{R-NH_2}$

ESTER 
$\mathrm{R-C(=O)-O-R^1}$

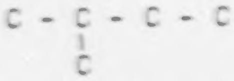
ETHER R - O - R

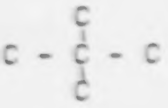
HALIDE R - X

KETONE 
$\mathrm{R-C(=O)-R^1}$

5. These are compounds with the same structural formulas but different structures

C_5H_{12}


$\mathrm{C-\underset{C}{C}-C-C}$


$\mathrm{C-\overset{C}{\underset{C}{C}}-C}$

6. Proteins are polymers of amino acids. They are complex organic molecules which are found in every living molecule.

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Name ______________________________

MODULE E1 - 6 EXAMINATION

1. Explain the meaning of the following:

   a. hydrocarbon

   b. aromatic

   c. aliphatic

   d. saturated

   e. unsaturated

   f. alkane

   g. alkene

   h. alkyne

   i. acetylene

   j. isomer

   k. cis-trans

2. A man is examined in a hospital and it is determined that he is suffering from liver and brain damage. What is a possible cause of his problem?

MODULE E1 - 6 EXAMINATION SOLUTION SET

1. a. Compounds which contain only hydrogen and carbon.

   b. Compounds with structures related to that of the benzene molecule.

   c. Compounds that have a moncyclic structure.

   d. Compounds which contain only single bonds between carbon atoms.

   e. Compounds which have double and triple bonds between carbon atoms.

   f. Hydrocarbons that contain single covalent bonds between carbon atoms.

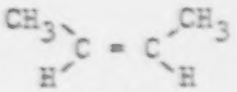
   g. Hydrocarbons that contain double bonds between carbon atoms.

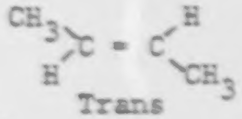
   h. Hydrocarbons that contain triple bonds between carbon atoms.

   i. Another name for alkynes.

   j. Molecules which have the same structure but different structures.

   k. Molecules having R groups on opposite sides of a molecule


Cis


Trans

2. Excess prolonged use of fluids containing ethanol.

Name ______________________

MODULE E1 - 7 EXAMINATION

1. What is meant by the chemistry of organic compounds?

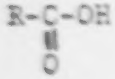
2. You smell something which smells of mint. What type of a chemical might you be smelling?

3. State several industrial uses of organic compounds:

4. Name the following:

   a. R-H

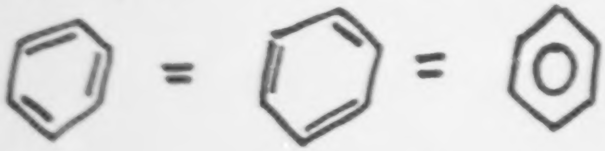
   b. R-OH

   c. 
   $R-\underset{\underset{O}{\|}}{C}-OH$

   D. $R-NH_2$

5. As the number of carbons in carbon compounds increase, what would you expect to happen to their melting points?

6. What is meant by the following diagram?



MODULE E1 - 7 EXAMINATION SOLUTION SET

1. This is the study of their reactions, reaction rates, products, physical parameters, chemical parameters, etc.

2. An ester.

3. Organic compounds are used in the manufacture of gas, plastics, alcohols, insulators, etc.

4. a. hydrocarbon

   b. alcohol

   c. acid

   d. amine

5. As the number of carbons in carbon compounds increases, the melting points should increase.

6. These are the three structures which represent a benzene ring.

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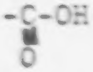
Name ____________________

MODULE E1 - 8 EXAMINATION

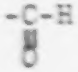
1. Name the following functional groups:

$-H$



$-\underset{\parallel}{\overset{}{C}}-OH$ with $=O$: $-C(=O)-OH$

$-OH$

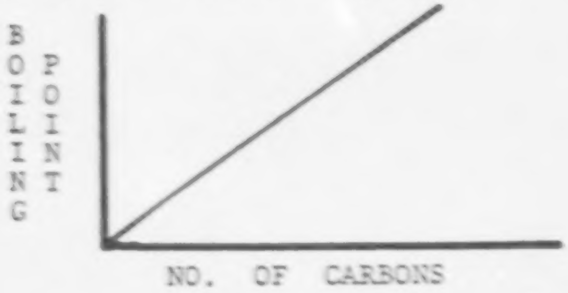


$-C(=O)-H$

2. What is organic chemistry?

3. In chemistry, what is a homologous series?

4. Interpret the following graph:



5. What are the physiological effects of consuming copious quantities of CH_3CH_2OH?

6. How is tetrahedral structure related to carbon chemistry?

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MODULE E1 - 8 EXAMINATION SOLUTION SET

1. a. hydrocarbon
   b. acid
   c. alcohol
   d. aldehyde

2. Organic chemistry is the chemistry of carbon compounds.

3. A series of compounds in which each successive member differs by a given amount. For example, in the alkane series, each successive member differs by one CH_2 group.

4. As the number of carbons in successive compounds increases, the boiling point increases.

5. Drunkenness and possibly death.

6. The carbon molecule is thought to sit in the middle of a tetrahedron with the four carbon bonds pointing toward the tetrahedrons four corners.

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Name ____________________________

MODULE E1 - 9 EXAMINATION

1. How can you account for the properties of organic compounds?

2. Define:

   a. chaining

   b. cis-trans isomerization

   c. structural isomerization

3. What is meant by $C_nH_{2n}+2$?

4. Name at least five functional groups:

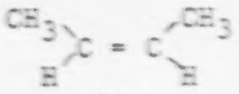
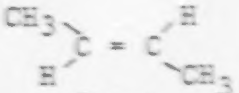
5. What is the meaning of ane, ene, yne?

6. Methane has one C atom, pentane has five C atoms, and decane has ten C atoms. What might you predict concerning the relative specific gravities of these compounds when they are in the liquid form?

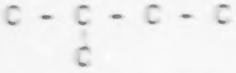
MODULE E1 - 9 EXAMINATION SOLUTION SET

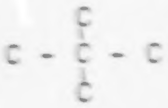
1. The properties of carbon can be accounted for by the types of bonds into which carbon is able to enter.

2. a. Carbon to carbon bonds in long strings or chains.

   b. 
   Cis
   
   Trans

   c. Compounds which have the same formula but different structures

   
   $\mathrm{C - \underset{C}{C} - C - C}$

   
   $\mathrm{C - \overset{C}{\underset{C}{C}} - C}$

3. This is the formula for successive members of the alkane series.

4. Alcohols
   Acids
   Aldehydes
   Ketones
   Esters
   Amines

5. a. -ane means carbon to carbon single bonds.

   b. -ene means carbon to carbon double bonds.

   c. -yne means carbon to carbon triple bonds.

6. The specific gravities will increase with increasing numbers of carbons.

Name ______________________

MODULE E1 - 10 EXAMINATION

1. Define the meaning of organic chemistry:

2. Discuss the solubility of carbon containing compounds:

3. What is an amino acid?

4. Define the following terms:
   a. cis-trans
   b. amine
   c. ester
   d. acid
   e. ketones
   f. alcohols
   g. halogens
   h. aldehydes

5. What is the difference between an alkane and alkene and an alkyne?

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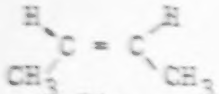
MODULE E1 - 10 EXAMINATION SOLUTION SET

1. The chemistry of carbon compounds.

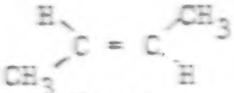
2. Carbon containing compounds are generally soluble in organic compounds.

3. Amino acids are organic compounds that contain an amine and an acid functional group.

4. a.



Cis



Trans

b. NH_2

c.

$R - \underset{\underset{O}{\|}}{C} - O - R^1$

d. COOH

e.

$R - \underset{\underset{O}{\|}}{C} - R^1$

f. OH

g. R-Cl; R-Br; R-I

h. COH

5. a. Alkane, compounds which have single carbon to carbon bonds.

   b. Alkene, compounds which have double carbon to carbon bonds.

   c. Alkyne, compounds which have triple carbon to carbon bonds.

TOXIC SUBSTANCES IN THE ENVIRONMENT

Module E2, Toxic Substances in the Environment, is the second of the elective series modules. As a result of studying this module, the student will be able to define and identify the following classes of toxic substances: metabolic, corrosive, neurotoxic, mutagenic and carcinogenic. Further, the student will be able to recognize the physiological effects of each class, identify the modes of action of the various classes, discuss the use of antidotes, and finally, be able to discuss haluoogens.

Advance your slide carrousel to slide number one. In this unit we will consider some of the toxic substances in our environment. Toxic refers to substances which cause harm in some chemical way. This is a very broad definition and needs to be narrowed for our purposes.

This slide shows a bag of Unidote universal antidote, and bottles of digitalis, paregoric, isopropyl alcohol, sodium penobarbital, and tincture of belladonna.

SLIDE #1

The human body is a complex system of chemical compounds. Life depends on the assembly of just the right amounts of different elements. There are mechanisms to regulate the intake of materials so that the right amounts of different elements are assured. These mechanisms operate within limits. When the body is presented with excessive amounts of a single element or compound a toxic reaction can be expected.

Sugar is toxic if large enough quantities are eaten. (Slide shows a pile of sugar.)

Copper compounds are lethal in very small quantities, but some copper is necessary for life. (Slide shows a pile of Cu -- copper.)

SLIDE #2

Advance to slide number two. Sugar is harmless except in extremely large doses. Taken in large enough amounts it is toxic. Copper is more toxic in that very small amounts are lethal yet some copper is necessary to sustain life. The term toxic is usually reserved for materials which, like copper, in small amounts upset the biochemical reactions of the body.

SOME TOXIC SUBSTANCES:

Ethyl alcohol - 5-15 grams per kg body weight

Methyl alcohol - 0.5-5 g/kg

Asperin - 50-500 mg/kg

Morphine - 1-50 mg/kg

SLIDE #3

Look at slide number three. Toxic substances may be classified in categories which are descriptive of the way they disrupt body chemistry.

CLASSES OF TOXIC SUBSTANCES:

CORROSIVE

METABOLIC

NEUROTOXIC

MUTAGENIC

CARCINOGENIC

SLIDE #4

Look at slide number four. These terms name the types of biochemical processes which are disturbed. We will consider them one at a time.

Corrosive poisons react locally on tissues. Examples include strong acids, alkalies, and many oxidants such as those found in laundry products. These materials dehydrate, hydrolyze and oxidize cellular tissues.

Advance to slide number five. Concentrated sulphuric acid will take the water out of cellulose molecules, leaving only the carbon which is black. One ounce of concentrated sulphuric acid, if swallowed, would probably result in death.

This slide shows a bottle of concentrated H_2SO_4.

SLIDE #5

Look at slide number six. Corrosive materials also work by hydrolysis of the peptide or protein link. Proteins are broken down to acids and amines. Some of these materials work by oxidizing tissue. They destroy enzymes by oxidizing their functional groups. Ozone and nitrogen dioxide are examples of these corrosive materials.

See Page 385A - Following

SLIDE #6

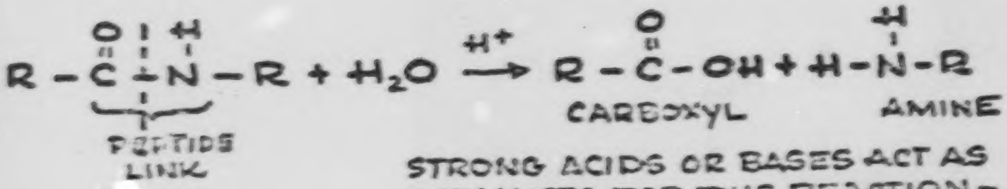
Look at slide number seven. The table lists some corrosive poisons. Hydrochloric acid is often shipped in tanks. It is used in many manufacturing processes. Its common name is muriatic acid.

See Page 385B - Following

SLIDE #7

Sulfuric acid, which also has wide industrial use, may also be shipped by

HYDROLYSIS



$$R-\underbrace{\overset{\overset{O}{\|}}{C}\overset{\vdots}{-}\overset{\overset{H}{|}}{N}}_{\text{PEPTIDE LINK}}-R+H_2O\xrightarrow{H^+}\underset{\text{CARBOXYL}}{R-\overset{\overset{O}{\|}}{C}-OH}+\underset{\text{AMINE}}{H-\overset{\overset{H}{|}}{N}-R}$$

STRONG ACIDS OR BASES ACT AS CATALYSTS FOR THIS REACTION - MAKING THEM VERY CORROSIVE TO PROTIENS.

SOME CORROSIVE POISONS

Substance	Formula	Toxic Action	Possible Contact
hydrochloric acid	HCl	acid hydrolysis	concrete floor cleaner
sulfuric acid	H_2SO_4	acid hydrolysis dehydrates tissue oxidizes tissue	auto batteries
phosgene	$ClCOCl$	acid hydrolysis	combustion of chlorine containing plastics - PVC
sodium hydroxide	$NaOH$	base hydrolysis	lye, drain cleaners
trisodium phosphate	Na_3PO_4	base hydrolysis	boiler water treatment chemical
sulfite ion	SO_2^{--}	reducing agent	boiler water treatment chemical
ozone	O_3	oxidizing agent	electric motors

SLIDE #7

sea. There is a 10 - 15% solution of it in storage in batteries. Its common name is oil of vitriol.

Some plastics such as saran and polyvinyl chlorides produce phosgene when burned. The PVC pipes are often used for drainage and soil pipes. If burned in an enclosed space such as the hold of a ship, the concentration would soon become lethal.

Sodium hydroxide, or caustic soda, is a strong base. When mixed with a strong acid, such as sulphuric acid, an explosive reaction takes place. Sodium hydroxide also hydrolyzes proteins. It has a slippery feel it it gets on your skin. Trisodium phosphate sometimes occurs in harmful concentrations in diluted commercial cleaners. You will use it as a chemical in boiler water treatment.

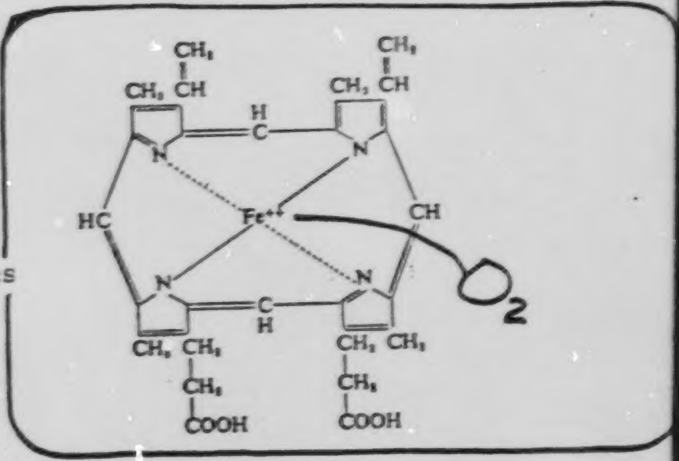
Ozone is generated by an arc. Electric motors in which excessive brush arcing occurs can produce harmful concentrations of ozone in small enclosed areas.

Nitrogen dioxide usually doesn't occur under ordinary circumstances. It is produced in an atmosphere polluted by a petrochemical smog (such as auto exhaust).

The hypochlorite ion you have met in the form of chlorox, a common household cleaner. One word of caution: when mixed with ammonia, also a common household cleaner, poisonous gas is generated.

Hydrogen peroxide is safe enough as an anticeptic in a 3% solution. In higher concentrations it is a powerful oxidizing agent.

Advance to slide number eight. Metabolic poisons do not destroy tissues directly. They cause illness or death by interfering with some biochemical mechanism so that the mechanism ceases to function effectively. Carbon monoxide is a common metabolic poison. It interferes with the ability of the hemoglobin in blood to pick up oxygen. Normally, oxygen in the lungs attaches itself to the iron in the hemoglobin molecule and travels to the cells. There the iron releases the oxygen, picks up a CO_2 and returns to the lungs. If carbon monoxide is present



SLIDE #8

it attaches itself to the iron just as the oxygen would but then will not let go. This, in effect, removes the hemoglobin molecules from the oxygen carrying system necessary to sustain life.

Look at slide number nine. The cyanide ion is the toxic agent in cyanide salts such as sodium cyanide, which is used in electroplating. The salts react with the acids to release hydrogen cyanide. Sometimes this reaction is used to produce HCN to fumigate the holds of ships. It is toxic to almost all forms of life and will even penetrate insect eggs.

$$\text{NaCH} + H^+ \rightarrow \text{HCN} + \text{Na}^+$$

Hydrogen, cynanide
or hydrocyanic
acid.

SLIDE #9

Cyanide is one of the most rapidly working poisons. Lethal doses taken by mouth act in minutes. Cyanide poisons by asphyxiation, as does carbon monoxide, by blocking oxidative enzymes so that each cell can no longer oxidize food.

WITH FUNCTIONING ENZYME:

$$\text{Glucose}+{}^{1}{}_{2}O_2 \xrightarrow[\text{catalyst}]{\text{enzyme}} CO_2 + H_2O + \text{ENERGY}$$

WITH BLOCKED ENZYME:

$$\text{Glucose}+{}^{1}{}_{2}O_2 \xrightarrow[\text{cn complex}]{\text{enzyme-}} \text{NO REACTION}$$

CELL DIES IN
MINUTES

SLIDE #10

Look at slide number ten. Metabolites, such as sugar, require enzymes to combine with oxygen in the cell. The cyanide ion reacts with the enzymes, rendering them ineffective so sugar cannot be oxidized.

Look at slide number eleven. Perhaps the most common of all the metabolic poisons are heavy metals. The heavy metals commonly found in the environment are Pb, Hg, As, Cd, and Cr. These, like cyanide, have the ability to react with and inhibit enzymes in the cells. In particular they destroy enzymes with -S-H bonds by combining permanently with active sites on the enzyme. The enzyme molecules thus inactivated must be replaced or the reaction reversed, a slow process that makes the heavy metals cumulative in their effect.

See Page 389A - Following

SLIDE #11

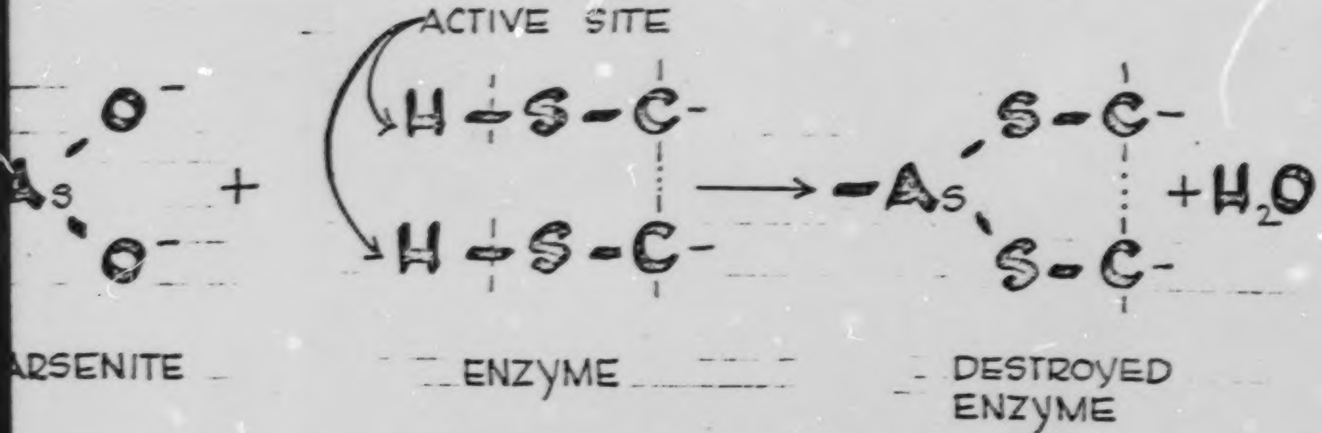
Look at slide number twelve. Arsenic is found in some medicine. Years ago it was used in cough medicine. Fruit trees are still sometimes sprayed with lead arsenate, since it does a good job on the bugs. An antidote for arsenic poisoning has been found. It is called BAL. It simply reacts with the metal more readily than the enzymes, leaving the enzymes to do their job.

SOME TOXIC HEAVY METALS:

Metal	Where It Might Be Found
Arsenic	Medicine, insect sprays.
Mercury	Fungicides, metal in instruments such as thermometers and pressure gauges, flourescent light fixtures.
Lead	Paint, gasoline, insect sprays, lead objects such as pipe or bullets.

SLIDE #12

Mercury and its compounds are toxic


ACTIVE SITE
As
O⁻
O⁻
+
H–S–C–
H–S–C–
–As
S–C–
S–C–
+H₂O
ARSENITE
ENZYME
DESTROYED ENZYME

SLIDE #11

and it is difficult for the body to dispose of them. They tend to slowly accumulate even at low level exposures. Its effect is particularly noticeable on the nervous system, causing shaking, insanity and sometimes complete loss of mental ability. In the last century, mercuric nitrate was used to stiffen felt hats. The people who worked as hatters often developed "hatter's shakes" or became "mad hatters".

Mercury salts are commonly used as a fungicide on seed grains. The metal itself can be absorbed through the skin. It is usually found in good grade thermometers. Electric switches sometimes contain mercury. Flourescant light bulbs contain mercury, and should be handled with care so they are not broken. BAL is also an antidote for mercury.

The effects of lead, like mercury, are readily seen in the central nervous system. They body can rid itself of about two milligrams of lead per day and quantities lower than the two milligrams per day are not cummulative. Lead can be removed from the body at higher rates by the use of ethylenediaminetetraacetic acid.

Lead is often found in old paint where it was used as a paint base. Most paints today use titanium oxide for the base. Gasoline contains tetraethyl lead which can be absorbed through the skin. Even metallic lead can be absorbed through the skin. There have been some cases where people developed lead poisoning as a result of handling lead foil, bullets, and other lead objects.

Advance to slide number thirteen. Neurotoxins limit their action to the nervous system. The exact modes of operation are not clearly understood but the neurotoxins interfere with the transmission of nerve impulses across the synapse between nerves. As you can see on the slide, many of the body's most important functions are interfered with by neurotoxins.

See Page 391A - Following

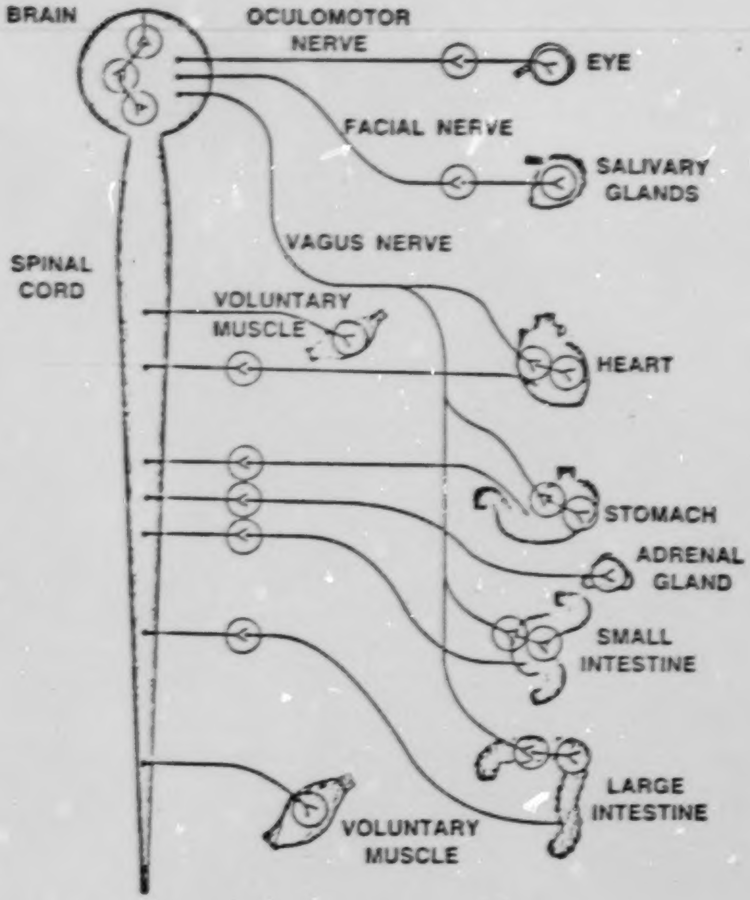
SLIDE #13

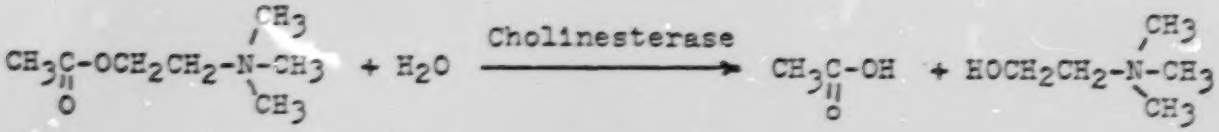
Look at slide number fourteen. The key chemical in the transmission of nerve impulses seems to be acetylcholine. The enzyme cholinesterase is required to break down the acetylcholine so that

See Page 391B - Following

SLIDE #14

SLIDE #13


BRAIN
OCULOMOTOR NERVE
EYE
FACIAL NERVE
SALIVARY GLANDS
VAGUS NERVE
SPINAL CORD
VOLUNTARY MUSCLE
HEART
STOMACH
ADRENAL GLAND
SMALL INTESTINE
LARGE INTESTINE
VOLUNTARY MUSCLE



$$CH_3\underset{\substack{\| \\ O}}{C}-OCH_2CH_2-\overset{CH_3}{\underset{CH_3}{N}}-CH_3 + H_2O \xrightarrow{\text{Cholinesterase}} CH_3\underset{\substack{\| \\ O}}{C}-OH + HOCH_2CH_2-\overset{CH_3}{\underset{CH_3}{N}}-CH_3$$

Acetylcholine

Water

Acetic acid

Choline

The reaction must go in this direction ⟶ if the nerve impulse is to be transmitted

SLIDE #14

the nerve impulses may be transmitted. Neurotoxins have structures similar to that of acetylcholine, tie up the cholinesterase, and thereby prevent the necessary reaction from taking place. Usually the toxins are bound permanently to the cholinesterase so that it must be replaced. This takes time and meanwhile excess acetylcholine overstimulates the nerves, glands, and muscles producing irregular heart rythms, convulsions and death.

Look at slide number fifteen. This slide illustrates the mechanism in the transmission of nerve impulses. An incoming nerve pulse causes the release of acelylcholine which stimulates a receptor. For the stimulation to cease, the acetylcholine must be decomposed. It can be decomposed to acetic acid and choline with the aid of the enzyme cholinesterase. Without the cholinesterase the receptor will remain stimulated; a muscle, for example, would not release.

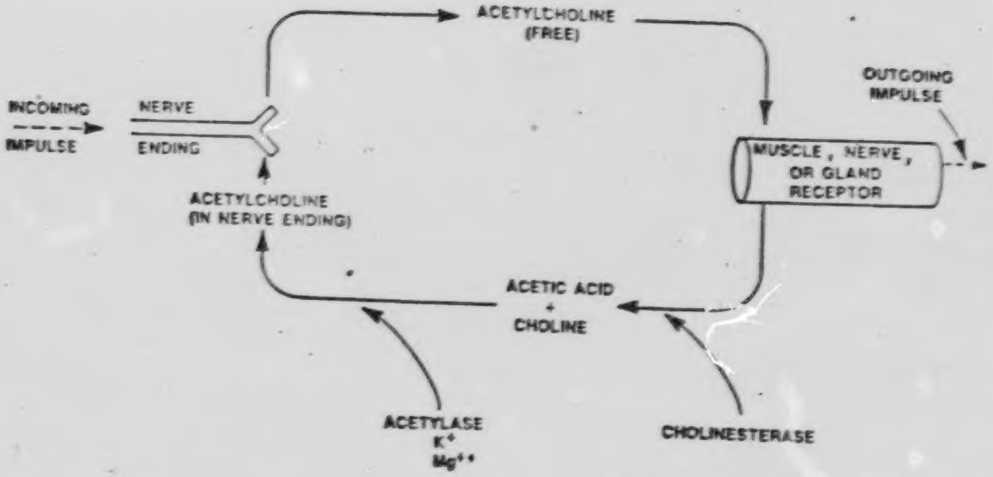
See Page 392A - Following

SLIDE #15

Look at slide number sixteen. The three vulnerable sites in the cycle are shown. The blockage of any one of

See Page 392B - Following

SLIDE #16



INCOMING IMPULSE

NERVE ENDING

ACETYLCHOLINE (FREE)

OUTGOING IMPULSE

MUSCLE, NERVE, OR GLAND RECEPTOR

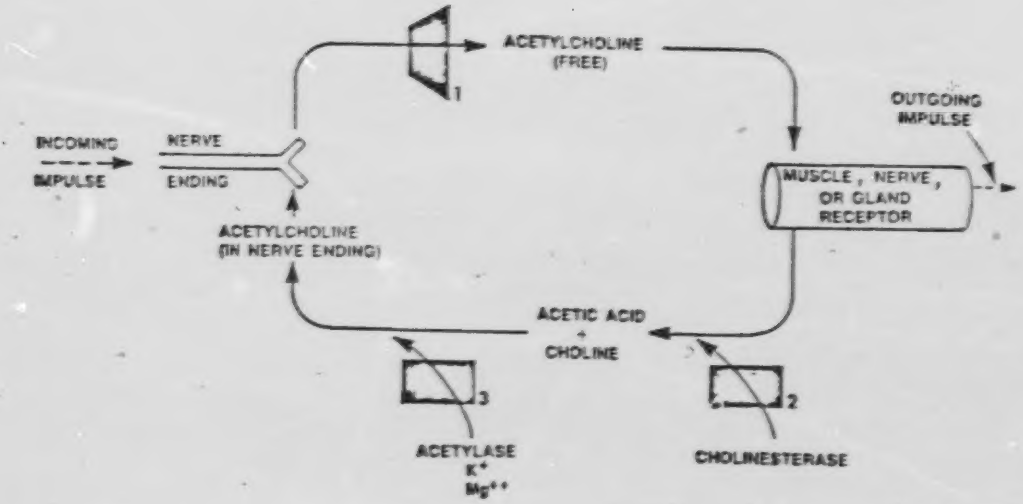
ACETYLCHOLINE (IN NERVE ENDING)

ACETIC ACID + CHOLINE

ACETYLASE K^+ Mg^{++}

CHOLINESTERASE

SLIDE #15



ACETYLCHOLINE
(FREE)

1

INCOMING
IMPULSE

NERVE
ENDING

OUTGOING
IMPULSE

MUSCLE, NERVE,
OR GLAND
RECEPTOR

ACETYLCHOLINE
(IN NERVE ENDING)

ACETIC ACID
+
CHOLINE

3

2

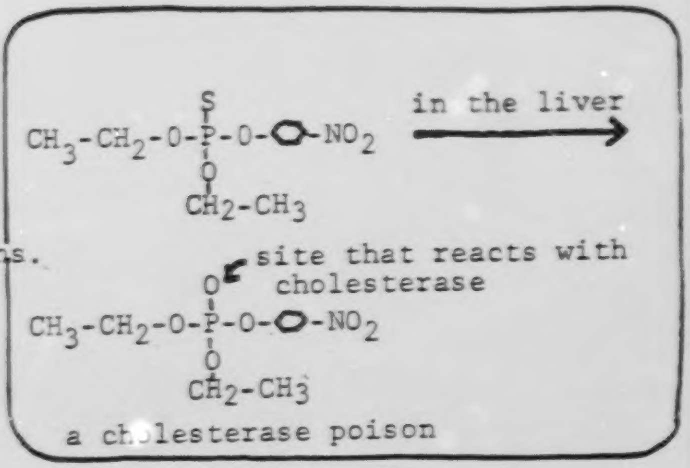
ACETYLASE
K^+
Mg^{++}

CHOLINESTERASE

SLIDE #16

these three sites will prevent the transmission of impulses. Many of the organic phosphates which are widely used as insecticides, such as parathion, are metabolized by the body to produce anticholesterase poisons.

Look at slide number seventeen. It is thought that the substitution of an O for the S on the phosphate causes the poison to react with the enzymes.


in the liver

site that reacts with cholesterase

a cholesterase poison

SLIDE #17

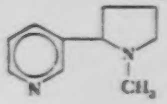
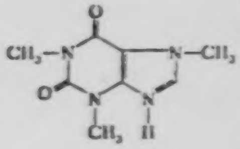
Look at slide number eighteen. Neurotoxins such as atropine occupy receptor sites on nerve endings which are normally occupied by impulse carrying acetylcholine thereby preventing reception of the stimulus. Atropine produces excessive thirst, dryness of the throat and mouth, rapid heart beat, and increase in blood pressure.

See Page 393A - Following

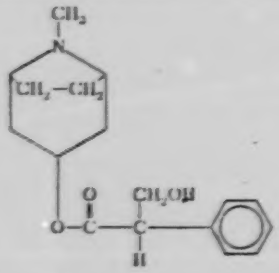
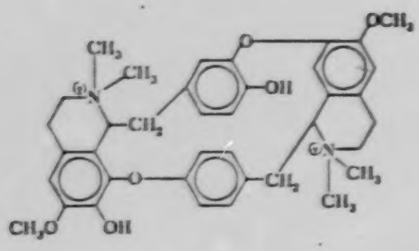
SLIDE #18

Neurotoxins of this kind can be extremely useful in medicine. For example, atropine is used by optometrists to dilate the pupil in the eye. Atropine salts relieve pain by deactivating sensory nerve endings on the skin.

Look at slide number nineteen. Nicotine is a compound that blocks

Nicotine	Tobacco insecticide	0.3 g	
Caffeine	Coffee, tea, cola drinks		

SLIDE #19

Atropine	Dilation of pupil of the eye	0.1 g	
Curare	Muscle relaxant		

SLIDE #18

receptor sites in a manner similar to that of atropine. This powerful poison causes stimulation then depression of the central nervous system.

Caffeine is a commonly used stimulant.

Look at slide number twenty. Morphine and codeine are commonly used pain killers.

See Page 394A - Following

SLIDE #20

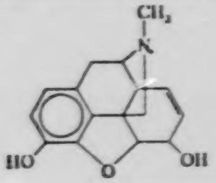
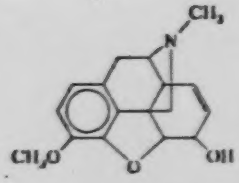
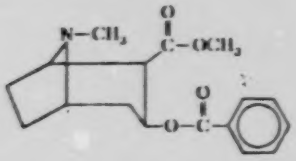
Advance to slide number twenty-one. Mutagens are chemicals capable of altering the genes and chromosones sufficiently to cause transmissible abnormalities in the offspring. In 1961 gross deformities occurred in children whose mothers had used the drug thalidomide during the first two months of pregnancy focusing attention on mutagens.

See Page 394B - Following

SLIDE #21

Thalidomide is used as a tranquilizer and sleeping pill. It was thoroughly tested on animals but its effects were discovered too late.

Actually thalidomide is not a true mutagen since it caused damage after conception had taken place. The materials listed on slide number twenty-one, however, are true mutagens.

Morphine	Opium— pain killer		
Codeine	Opium— pain killer	0.3 g	
Cocaine	Leaves of *Erythroxylon coca* in South America	1 g	

SLIDE #20

Aflatoxin (from mold, *Aspergillus flavus*)	Mutations in bacteria, viruses, fungi, parasitic wasps, human cell cultures, mice
Benzo(a)pyrene (from cigarette and coal smoke)	Mutations in mice
Caffeine	Chromosome changes in bacteria, fungi, onion root tips, fruit flies, human tissue cultures
Captan (a fungicide)	Mutagenic in bacteria and molds; chromosome breaks in rats and human tissue cultures
Dimethyl sulfate (used extensively in chemical industry to methylate amines, phenols, and other compounds)	Methylates DNA base guanine; potent mutagent in bacteria, viruses, fungi, higher plants, fruit flies
LSD (lysergic acid diethylamide)	Chromosome breaks in somatic cells of rats, mice, hamsters, white blood cells of humans and monkeys

SLIDE #21

Notice that many of them are widespread in our environment. Some, like benzopyrene in cigarette smoke and caffeine in coffee, tea, Coke, and other soft drinks, we subject ourselves to daily.

Look at slide number twenty-two. We are not aware of being subjected to others, such as nitrous acid and organic solvents. Nitrous acid comes in the form of sodium nitrate which is used as a preservative on most processed meats, hot dogs and baloney. Organic solvents such as toluene, acetone, and others are in such things as glue, gasoline, paints, and cosmetics.

See Page 395A - Following

SLIDE #22

Look at slide number twenty-three. Carcinogens are chemicals which cause cancer. These materials act on the mechanisms which control the growth of cells. The mechanisms and how carcinogens effect the cell are not known. If they were, we could probably devise a cure for cancer.

See Page 395B - Following

SLIDE #23

Look at slide number twenty-four. Read the chart AO to aromatic amines. B aromatic amines to A_{20} dyes.

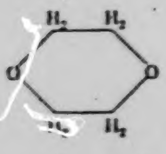
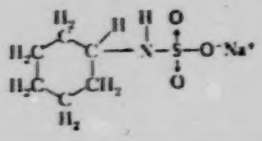
See Page 395C - Following

SLIDE #24

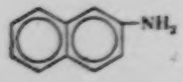
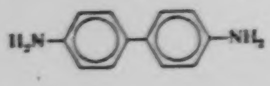
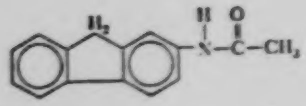
Look at slide number twenty-five.

Maleic hydrazide (plant growth inhibitor; Trade names Slo-Gro, MH-30)	Chromosome breaks in many plants and in cultured mouse cells
Mustard gas (dichlorodiethyl sulfide)	Mutations in fruit flies
Nitrous acid (HNO_2)	Mutations in bacteria, viruses, fungi
Ozone (O_3)	Chromosome breaks in root cells of broadleaf plants
Solvents in glue (glue sniffing) (toluene, acetone, hexane, cyclohexane, ethyl acetate)	4% more human white blood cells showed breaks and abnormalities (6% versus 2% normal)
TEM (triethylenemelamine) (anticancer drug, insect chemosterilants)	Mutagenic in fruit flies, mice

SLIDE #22

Compound	Use or Source	Formula of a Representative Compound
Carbon tetrachloride	Dry cleaning agent, solvent	CCl_4
Dioxane	Solvent in chemical industry, cosmetics, glues, deodorants	
Cyclamates	Artificial sweeteners	

SLIDE #23

Aromatic amines		
2-Naphthylamine	Optical bleaching agent	
Benzidine	Polymer formation, manufacture of dyes, stain for tissues, rubber compounding	
N-2-Fluorenylacetamide	Herbicide	

SLIDE #24

Advance to slide number twenty-six. Hallucinogens are chemicals which produce temporary changes in perception, throught, and mood. Some of the more famous ones are listed on slide number twenty-six. Scientists are not in agreement on the toxic effects of these materials, though it has been established that LSD is at least mutagenic in animals.

Hallucinogens apparently work by freeing nerve impulses that are normally blocked in the brain. The random sets of nerve impulses that reach the conscious level possibly cause the effect.

The chemical basis for many toxic effects are known. For others, only the effect is known. In a broad sense, toxic substances either destroy some important biochemical process by hydrolysis, oxidation, or reduction or intefere with some important molecule's function by combining with it. Probably most toxic substances inhibit enzymes to achieve their effect.

Look at slide number twenty-seven. As a result of your study with this

See Page 396A - Following

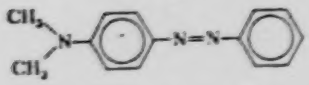
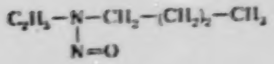
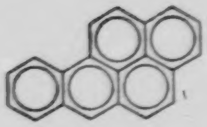
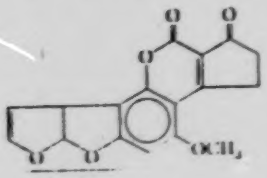
SLIDE #25

See Page 396B - Following

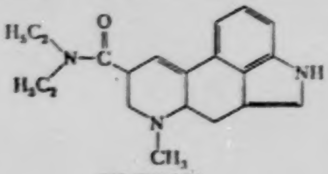
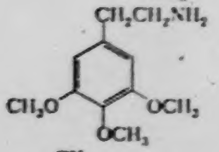
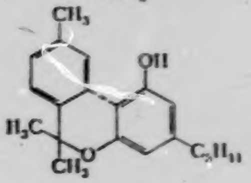
SLIDE #26

CORROSIVE
METABOLIC
NEUROTOXIC
MUTAGENIC
CARCINOGENIC

SLIDE #27

Azo dyes		
N, N-Dimethyl-p-phenyl-azoaniline	Yellow dye (once used as a food color)	
Nitrosoamines		
N-Ethyl-N-nitroso-n-butylamine	Insecticide, gasoline and lubricant additive	 $C_2H_5-\underset{N=O}{\underset{\mid}{N}}-CH_2-(CH_2)_2-CH_3$
Polynuclear compounds		
Benzo(a)pyrene	Cigarette and coal smoke	
Aflatoxin	Mold on peanuts and other plants (*Aspergillus flavus*)	

SLIDE #25

CHEMICAL	ALIASES	NOTES	ACTIVE COMPOUND	FORMULA
LSD	Acid Crackers The chief The hawk	Very powerful hallucinogen	D-Lysergic acid diethylamide	
Mescaline		Extracted from mescal buttons from peyote cactus in South and Central America	3,4,5-Trimethoxyphenethylamine	
Marijuana	Grass Pot Reefers Locoweed Hash Mary Jane	Leaves of the 5-leaf-per-frond marijuana plant (*Cannabis sativa*)	3,4-Trans-tetrahydrocannabinol	
Amphetamines	Pep pills Speed Bennies Ups	Eighteen times more active than mescaline	2,4,5-Trimethoxyamphetamine (for example)	

SLIDE #26

module, you should be able to use the vocabulary. Also, you should be able to explain, in general terms, the effects of each of the five classes of toxic substances and generally how these effects are achieved.

MODULE E-2 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the MODULE E-2 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE E-2 as well as to the completion of the problem set. Those pages are: 5-24, 62, 76, 200, 203, 222, 223, 246, 247, 264, 273, 282-298.

Problem Set

Use the problem set for MODULE E-1 if you have not already completed that set. There is no additional problem set for this module; however, E-1 problem set must be completed. (Page 300; Problems 1, 2, 3, 5, 7 and 10) The questions should be answered and submitted to your instructor. They should be neatly written and each successive step in the solution should be shown.

Name ______________________________

MODULE E2 - 1 EXAMINATION

1. Define the term "toxic":

2. Name 5 classes of toxic materials and give examples of each:

3. For each class listed above give the physiological effect, the mode of action and the antidote. (State how poison can be counteracted or avoided.)

4. What is a halucogen? How does a halucogen cause its effect?

MODULE E2 - 1 EXAMINATION SOLUTION SET

1. Toxic refers to substances which cause harm in some chemical way.

2. The five classes of toxic substances are:
   a. Corrosive - hydrochloric acid
   b. Metabolic - cyanide
   c. Neurotoxic - atropine
   d. Mutagenic - thalidomide
   e. Carcinogenic - cigar smoke

3. a. They act locally on the skin to dehydrate, hydrolyze and oxidize cellular tissues. They also break peptide bond links. They can usually be cleared by washing the skin.

   b. Metabolic poisons cause illness or death by interfering with a biochemical mechanism so that it ceases to function. In many cases there is no antidote. However, a substance called BAL is the antidote for arsenic.

   c. Neurotoxins interfere with the transmissions of nerve impulses and can cause irregular heart rythms, convulsions and death. In many cases there are no antidotes.

   d. These chemicals are capable of altering the genes and chromosomes sufficiently to cause transmissible abnormalities in offspring. There is generally no antidote.

   e. Carcinogens are chemicals that cause cancer by action on the mechanisms which control growth. There is no antidote.

4. Hallucinogens are chemicals which produce temporary changes in perception, thought and mood. They work by freeing nerve impulses whose paths to the brain are normally blocked.

Name ______________________

MODULE E2 - 2 EXAMINATION

1. Define the following terms:

   a. toxic

   b. mode of action

   c. antidote

   d. halucogen

2. What are the physiological effects of each of the five classes of toxic substances?

MODULE E2 - 2 EXAMINATION SOLUTION SET

1. a. Toxic refers to substances which cause harm in some chemical way.

   b. This is the route which a toxin takes in order to produce the observable effects.

   c. This is a chemical which counteracts or neutralizes a toxin so that the toxin will not be effective.

   d. Hallucinogens are chemicals which produce temporary changes in perception, thought and mood. They work by freeing nerve impulses whose paths to the brain are normally blocked.

2. a. Corrosive poisons act locally on the skin to dehydrate, hydrolyze and oxidize cellular tissues. They also break peptide bond links. They can usually be cleared by washing the skin.

   b. Metabolic poisons cause illness or death by interfering with a biochemical mechanism so that it ceases to function. In many cases there is no antidote. However, a substance called BAL is the antidote for arsenic.

   c. Neurotoxins interfere with the transmissions of nerve impulses and can cause irregular heart rythms, convulsions and death. In many cases there are no antidotes.

   d. Mutagens are chemicals capable of altering the genes and coromosomes sufficiently to cause transmissible abnormalities in offspring. There is generally no antidote.

   e. Carcinogens are chemicals that cause cancer by action on the mechanisms which control growth. There is no antidote.

Name ______________________________

MODULE E2 - 3 EXAMINATION

1. Define the following terms:

   a. neurotoxic

   b. mutagenic

   c. carcinogenic

2. Discuss the mode of action of each of the five classes of toxic substances.

3. What is a halucogen and how does it create its effect?

MODULE E2 - 3 EXAMINATION SOLUTION SET

1. a. Neurotoxins interfere with the transmission of nerve impulses and can cause irregular heart rythms, convulsions and death. In many cases there are no antidotes.

   b. Mutagenic poisons are chemicals capable of altering the genes and chromosomes sufficiently to cause transmissible abnormalities in offspring. There is generally no antidote.

   c. Carcinogens are chemicals that cause cancer by action on the mechanisms which control growth. There is no antidote.

2. a. Corrosive poisons act locally on the skin to dehydrate, hydrolyze and oxidize cellular tissues. They also break peptide bond links.

   b. Metabolic poisons cause illness or death by interfering with a biochemical mechanism so that it ceases to function.

   c. Neurotoxins interfere with the transmission of nerve impulses and can cause irregular heart rythms, convulsions and death.

   d. Mutagens alter genes and chromosomes sufficiently to cause transmissible abnormalities in offspring.

   e. Carcinogens cause cancer by action on the mechanisms which control growth.

3. Hallucinogens are chemicals which produce temporary changes in perception, thought and mood. They work by freeing nerve impulses whose paths to the brain are normally blocked.

Name ______________________

MODULE E2 - 4 EXAMINATION

1. Both copper and sugar are toxic to the human body yet required to sustain life. How can you account for this?

2. What does it mean when something is labeled a corrosive toxin?

3. What mode of action is taken by metabolic poisons?

4. What is the result of enzyme inhibition and what are four elements which cause this type of activity?

5. A person complains of excessive thirst, and dryness of the mouth and throat. When the person is examined it is found that the person has a rapid heart beat and elevated blood pressure. What type of a toxin might this person have ingested?

MODULE E2 - 4 EXAMINATION SOLUTION SET

1. The amounts of these substances required to sustain life is small, and in small enough amounts these agents are not toxic.

2. Corrosive toxins act locally on the skin to dehydrate, hydrolyze and oxidize cellular tissues. They also break peptide bond links. They can usually be cleared by washing the skin.

3. Metabolic poisons cause illness or death by interfering with a biochemical mechanism so that it ceases to function. In many cases there is no antidote. However, a substance called BAL is the antidote for arsenic.

4. Enzyme inhibition is caused by heavy metals such as Pb, Hg, As, Cd, and Cr. The eventual result of this process may eventually be death.

5. A neurotoxin, probably atropine.

Name ______________________

MODULE E2 - 5 EXAMINATION

1. A toxin is found to interfere with acetylcholine and cholinesterase activity. In what category might this toxin be placed?

2. A person is seen smoking a cigar. To what type of toxin is the person exposing himself, and what is one possible result of long term exposure to these types of toxins?

3. A child is born to a woman who during pregnancy was on medication because of a sleeping problem. What type of (by name) pill might she have taken for her problem, what class of toxin is this and what is its mode of operation?

4. All toxins are said not to always be toxic. Explain this statement.

MODULE E2 - 5 EXAMINATION SOLUTION SET

1. Neurotoxin
2. A carcinogenic toxin. Its long term use may result in cancer.
3. Thalidomide which is sometimes classified as a mutagen but is not a true mutagen.
4. Some agents are toxic in large amounts but in small amounts are necessary for life.

Name ____________________________

MODULE E2 - 6 EXAMINATION

1. Doctors often tell pregnant women that when they smoke their unborn children smoke. Discuss the possible toxic effects on both the mother and child due to this type of activity.

2. A person is seen to be acting strangely after the ingesting of a substance known as LSD. What type of a toxin is this and what is its possible mode of operation?

3. Define the following terms:

   a. toxic

   b. antidote

   c. neurotoxin

   d. corrosive toxin

MODULE E2 - 6 EXAMINATION SOLUTION SET

1. The possible toxic effect upon a mother who smokes is cancer. As a result of the mother's smoking, the child may be born with birth defects since oxygen supply during periods of smoking is reduced and additionally, some carbon monoxide may be introduced into the system.

2. Hallucinogens are chemicals which produce temporary changes in perception, thought and mood. They work by freeing nerve impulses whose paths to the brain are normally blocked.

3. a. Toxic refers to substances which cause harm in some chemical way.

   b. An antidote is a chemical which neutralizes the activity of a toxin.

   c. Neurotoxins interfere with the transmissions of nerve impulses and can cause irregular heart rythms, convulsions and death. In many cases there are no antidotes.

   d. Corrosive poisons act locally on the skin to dehydrate, hydrolyze and oxidize cellular tissues. They also break peptide bond links. They can usually be cleared by washing the skin.

Module E2
P. 411

Name ______________________________

MODULE E2 - 7 EXAMINATION

1. A person parks his car during the winter because he is tired and must rest. However, the car engine is left running. The next morning the person is found dead, and the motor is still running. Discuss the situation in detail.

2. A person pours a 15% solution of H_2O_2 (hydrogen peroxide) on his skin. The area starts to change color and becomes sore. How can this be explained?

3. Some toxic substances are said to interfere with peptide bonds. What might be the result of this activity?

4. Define:

   a. mad hatter

   b. neurotoxin

MODULE E2 - 7 EXAMINATION SOLUTION SET

1. The individual has been introduced to carbon monoxide poisoning. Carbon monoxide is classified as a metabolic poison.

2. The person has poured a fluid on his or her arm which was in a concentration sufficient to make it corrosive.

3. These are corrosive toxins. If taken internally they could cause death while if introduced to the skin externally they would cause severe burning.

4. a. This is a condition which results from mercuric nitrate poisoning. It often developed in the hatters during the last century.

   b. Neurotoxins interfere with the transmissions of nerve impulses and can cause irregular heart rythms, convulsions and death. In many cases there are no antidotes.

Name ______________________________

MODULE E2 - 8 EXAMINATION

1. A child begins to suffer greatly after ingesting a chemical in an unmarked bottle. A doctor gives the child a shot and the child is soon seen to respond. Explain what has happened.

2. Define the following terms:

   a. peptide bond

   b. protein

   c. halucogen

3. What are the five categories of toxins? Give an example of each:

MODULE E2 - 8 EXAMINATION SOLUTION SET

1. The child had ingested a toxin and the doctor had administered an antitoxin.

2. a. A peptide bond is the bond between amino acids which eventually results in the formation of a protein.

   b. A protein is a molecule formed by the union of amino acids.

   c. Hallucinogens are chemicals which produce temporary changes in perception, thought and mood. They work by freeing nerve impulses who paths to the brain are normally blocked.

3. a. Corrosive - hydrochloric acid

   b. Metabolic - cyanide

   c. Neurotoxic - atropine

   d. Mutagenic - thalidomide

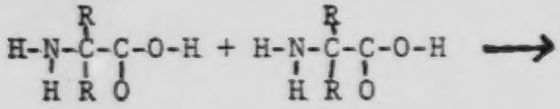
   e. Carcinogenic - cigar smoke

P. 415

Name ____________________

MODULE E2 - 9 EXAMINATION

1. In the reaction shown below, what is the result and what might happen if reactions of this type could not occur?



$$\mathrm{H{-}\underset{H}{N}{-}\overset{R}{\underset{R}{C}}{-}\underset{O}{C}{-}O{-}H + H{-}\underset{H}{N}{-}\overset{R}{\underset{R}{C}}{-}\underset{O}{C}{-}O{-}H} \longrightarrow$$

2. What type of toxin might interfere with this type of reaction (above)?

3. A person appears to suddenly become spastic after drinking from an unlabeled bottle. The first thought on the part of a physician is that acetylcholine and cholinesterase activity have been disrupted. Evaluate this situation.

4. People are often told not to handle mercury and lead. How can this be explained and what might be the results of this activity?

MODULE E2 - 9 EXAMINATION SOLUTION SET

1. The result of this reaction is the formation of a peptide bond and an H_2O molecule. Life would be impossible if this type of reaction could not occur.

2. A corrosive toxin.

3. The person may have been introduced to a neurotoxin.

4. Mercury and lead are taken in through the skin. The two agents are metabolic poisons and introduced in sufficient quantities can cause death.

Name ______________________________

MODULE E2 - 10 EXAMINATION

1. Smoking, among other things, is said to be carcinogenic. What should this mean to a woman who smokes?

2. The woman in number one becomes pregnant and is told to stop smoking by her physician. The physician explains that when she smokes her unborn child also smokes. Explain what is meant by the doctors comments.

3. A child is born without feet to a mother who, during pregnancy, was very nervous. Explain this situation.

4. Define:

   a. antidote

   b. transmissible abnormalities

   c. toxin

5. Some sodium compounds are toxic to humans and also found in food consumed by humans. Name at least two of these foods.

MODULE E2 - 10 EXAMINATION SOLUTION SET

1. She may contract cancer if the use of this toxin is prolonged.

2. The possible toxic effect upon a mother who smokes is cancer. As a result of the mother's smoking, the child may be born with birth defects since oxygen supply during periods of smoking is reduced and additionally, some carbon monoxide may be introduced into the system.

3. During pregnancy, the mother probably took thalidomide. Thalidomide tends to arrest certain portions of development during gestation.

4. a. An antidote is a chemical which neutralizes the activity of a toxin.

   b. These are possible results of the introduction of mutagenic agents. The result is chromosomal aberations which usually cause abnormalities to occur in siblings.

   c. Toxin refers to substances which cause harm in some chemical way.

5. Hot dogs and baloney.

WATER POLLUTION AND WASTE TREATMENT

Module E3, Water Pollution and Waste Treatment, is an elective module.

As a result of studying this module the student will understand, be able to discuss, and apply the concepts surrounding the following classes of pollution: oxygen demanding, infectious agent, plant nutrient, organic chemical, inorganic and mineral, sediment, radioactive, and heat. The student will also be able to apply remedies to pollution situations. Further, the student will be able to demonstrate the principles of the following types of water pollution: distillation, ion exchange, electrodialysis, and reverse osmosis. Finally, the student will be able to outline and discuss a shipboard sewage treatment system.

In this module we will be concerned with some forms of water pollution and waste treatment. We will briefly look at some classes of water pollutants and discuss the general principles for removing these pollutants. After that we will look at a system for treating sewage aboard ship.

Now advance to slide number one. Pollutants can be classified a number of ways. This scheme seems to be a satisfactory way of grouping pollutants. We will consider the first five classes in greater detail.

See Page 420A - Following

SLIDE #1

Oxygen demanding wastes often reduce the oxygen content of the water to the point where life is no longer possible. Infectious agents cause disease. Plant nutrients cause excessive plant growth which dies and becomes oxygen demanding waste as it decomposes. Organic chemicals are often toxic as are minerals and other chemicals. Sediment from land errosion kills some forms of life. Radioactive substances are a long range menace. Heat from the generation of power changes the ecological balance of a body of water.

Look at slide number two. Oxygen demanding wastes are decomposed by bacteria. It is the bacteria that require oxygen. Most of the oxygen demanding material is plant material which is primarily cellulose. The

$$\underset{\text{cellulose}}{(C_6H_{12}O_6)_x} + \underset{\text{from water}}{O_2} \rightarrow CO_2 + H_2O$$

SLIDE #2

Classes of Water Pollutants

1. Oxygen demanding wastes - plant and animal material
2. Infectious agents - bacteria and viruses
3. Plant nutrients - agricultural fertilizers such as nitrates
4. Organic chemicals - pesticides such as DDT
5. Other minerals and chemicals - inorganic chemicals from varours manufacturing processes
6. Sediment from land erosion - clay and silt
7. Radioactive substances - waste radioisotopes, waste from atomic power plants
8. Heat from industry - cooling water used in steam generation of electricity

SLIDE #1

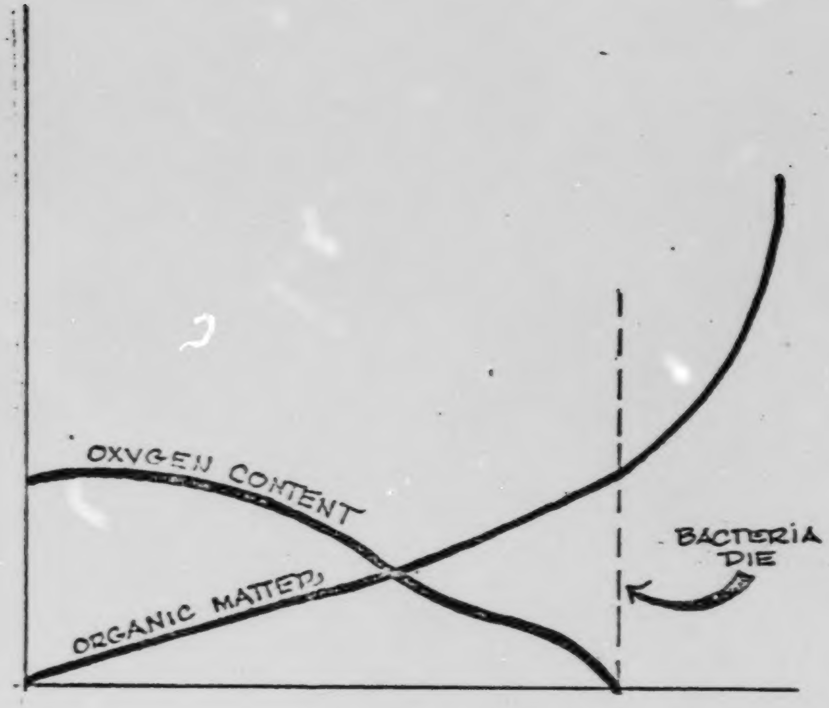
bacteria live by oxidizing the cellulose to carbon dioxide and water, using up the dissolved oxygen in the water in the process.

Oxygen dissolves in water, but rather slowly. A shallow stream running over rocks usually does not lack oxygen and fairly large amounts of cellulose can be oxidized. The problem becomes critical, however, when the oxygen supply is low and the organic content is high. If the organic content is high enough, the oxygen content may drop so low that the bacteria are killed and decomposition ceases.

See Page 421A - Following

SLIDE #3

Look at slide number three. As more and more organic matter is added, bacterial activity increases lowering oxygen content until bacteria die. When this happens matter can no longer decompose and the amount increases rapidly. This is basically how a bog is formed. Plant material is deposited fast enough to lower oxygen content so that most bacteria cannot live and the organic matter just piles up. The coal



SLIDE #3

deposits laid down in Pennsylvania probably underwent this process. A few bacteria that can use sulphur instead of oxygen to obtain their energy can still live. This accounts for the foul smell of the gases that come up in a bog.

The way to eliminate oxygen demanding pollution is simply to reduce the amount of organic material that is allowed to enter our waters. We will talk briefly about how this can be done in the last section of this module.

Infectious agents need to be kept out of our waters for obvious reasons. The last thing we need are epidemics of diseases such as cholera or typhoid.

Look at slide number four. Plant nutrients used in agriculture are of many kinds, but the three used in largest quantity are nitrogen, phosphorus, and potassium. The nitrogen may be in an organic form such as synthetic urea or in an inorganic form such as ammonia or nitrate salts. Phosphorus is usually

FERTILIZERS

Nutrient	Form
N	Ammonia, urea, nitrate
P	Phosphates
K	Salts

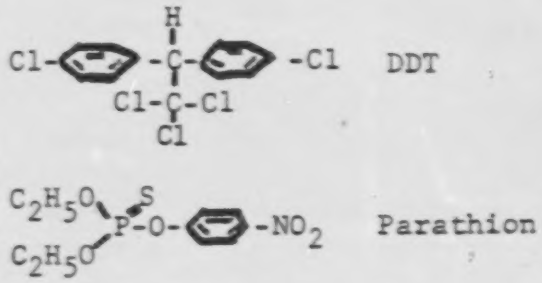
SLIDE #4

in the form of phosphates and potassium as a salt.

All three are highly soluble in water and are consequently easily leached from the land by rain. Run-off water carries them to lakes and streams where the aquatic plants utilize them and grow rapidly. If the growth rate of these plants is greater than the rate at which they are eaten they are decomposed by large numbers of bacteria and the oxygen level drops. Then we have the problem we discussed before and the lake dies.

Look at slide number five. The structures of two pesticides are shown here. Organic chemicals include such things as dyes, pesticides, industrial solvents, oil, etc. All of these are eventually decomposed in nature. The trick is not to put them into the environment faster than they can be decomposed.

SOME ORGANIC CHEMICALS AS POLLUTANTS



SLIDE #5

Look at slide number six. It shows a partial list of industrial wastes that often appear in our waters in large quantities. Most of these materials could be removed or

SOME EXAMPLES OF INDUSTRIAL WASTES
ACIDS - such as sulfuric, nitric
BASES - such as sodium hydroxide
SALTS - table salt (sodium chloride)
METAL SOLUTIONS - mercury, lead, iron, tin
OILS - fuels, lubricants
EMULSIFYING AGENTS - detergents
SCRAP PAINT AND ANIMAL WASTES - from food processing
DYES - manufacture of cloth
WASTE SOLVENTS - acetone, trichloroethylene
POISONS - cyanides, chlorine

SLIDE #6

recycled; however, at some extra cost.

Look at slide number seven. Sediment from land errosion can be controlled to some extent by systems of dams and proper agricultural practices. Radioactive substances pose a problem since there is no agreed upon satisfactory method of their disposal. Dumping at sea and storing in empty wells are methods which have been used. Heat from power plants is being dumped into our streams. At the present some attempt is being made to locate power plants where they do minimal harm to the environment.

POLLULTANT	CONTROL MEASURES
Sediment	Contour plowing, not disturbing natural vegitation, reseeding stripped land, flood control
Radioactive Substances	Dilute in sea or store
Industrial Heat	Proper location of power stations for generating electricity

SLIDE #7

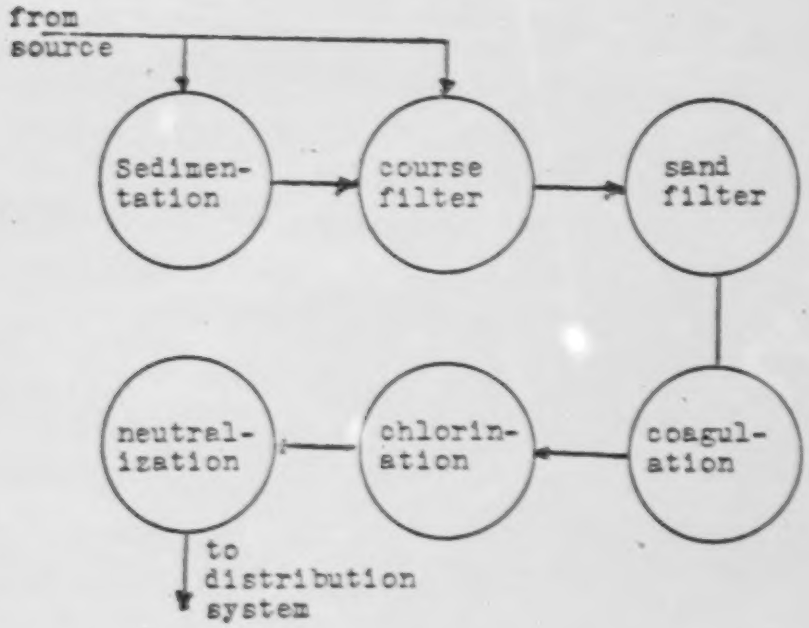
Look at slide number eight. Water can be purified by many methods but most of our water is made usable by the method shown on slide number eight. Most municipal water supplies are processed in a manner similar to this one.

See Page 424A - Following

SLIDE #8

The pinciple of the purification is to remove most of the particulate material and kill the microorganisms in the water. The first process is a coarse screening. This takes out the

Schematic Diagram of a Water Purification System



from source

Sedimentation

course filter

sand filter

coagulation

chlorination

neutralization

to distribution system

SLIDE #8

leaves, logs, beer cans, dead cats, etc. After screening, the water is usually passed through a sand filter. The sand filter removes the finer suspended particles. If the source of the water is a lake, most of the particles have settled anyway. If very fine particles come through the sand filter, they can be settled out by adding a coagulant such as aluminum hydroxide. After the water is clear, it is chlorinated in order to kill the bacteria. Sometimes lime is added to increase the pH so that less damage is done to the water distribution system.

Advance to slide number nine. The process here is similar to the schematic diagram of slide number eight.

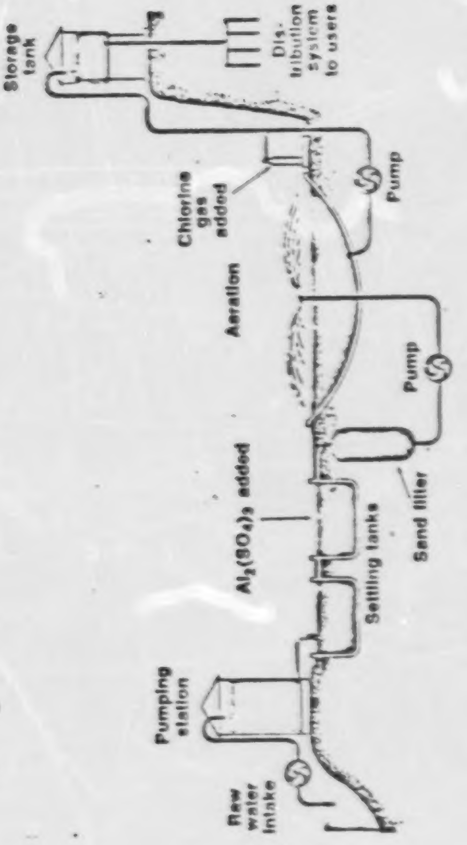
See Page 425A - Following

SLIDE #9

Look at slide number ten. The production of fresh water from the sea is becoming an economically important subject in many areas of the world. You will be in charge of the evaporators aboard a ship which utilize one of the basic principles for getting fresh water from sea water

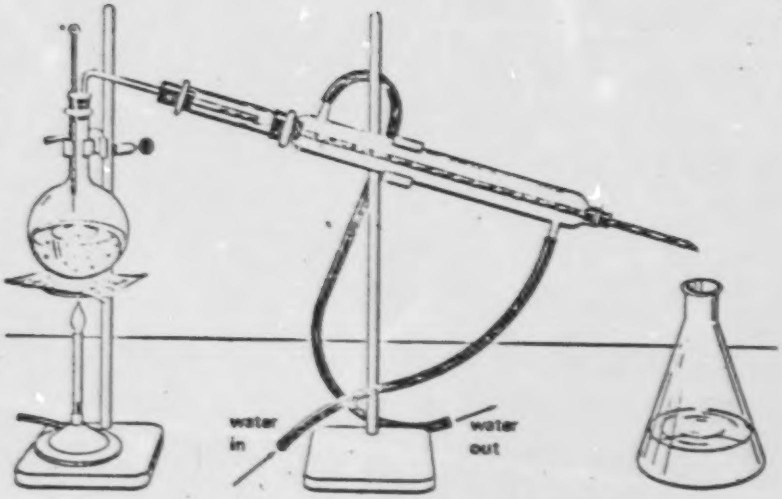
See Page 425B - Following

SLIDE #10


Raw water intake
Pumping station
Settling tanks
$Al_2(SO_4)_3$ added
Sand filter
Pump
Aeration
Chlorine gas added
Pump
Storage tank
Dis-tribution system to users

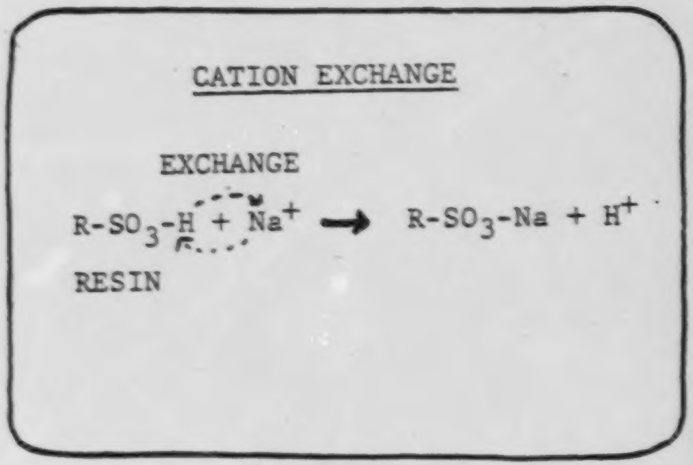
SLIDE #9

SLIDE #10


water in
water out

(distillation). Slide number ten illustrates a simple laboratory distillation apparatus which you have undoubtedly seen. Distillation cannot be used, however, to remove materials which vaporize at temperature less than the boiling point of water. The materials which vaporize and redissolve in the distilled water are called "carry over" and include dissolved gases, as well. Silica, under high pressure, crosses over. Distillation is an expensive process for purifying H_2O.

Look at slide number eleven. Another method of water purification commonly used is ion exchange. Some organic resins have the ability to bond to either cations, that is, positive ions, or to anions.



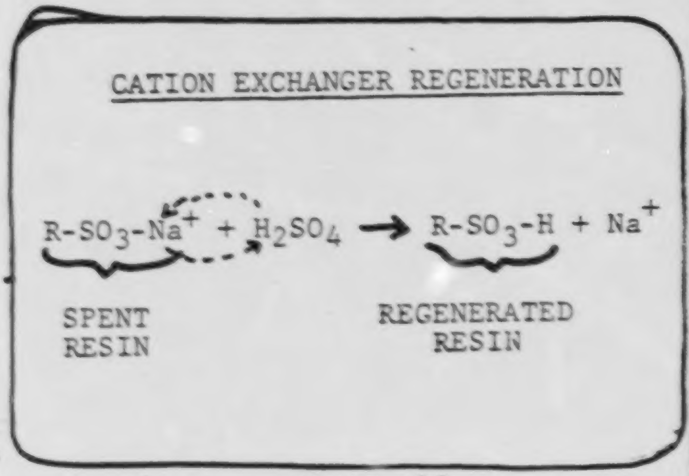
CATION EXCHANGE

EXCHANGE

$$\underset{\text{RESIN}}{R\text{-}SO_3\text{-}H} + Na^+ \rightarrow R\text{-}SO_3\text{-}Na + H^+$$

SLIDE #11

Look at slide number twelve. Cation exchangers are usually organic derivatives of sulphuric acid. They take out the metal ions and put in H^+ ions until the exchanger is saturated, that is, until all of the removable hydrogens in a given quantity of resin have been removed. Then the resin must



CATION EXCHANGER REGENERATION

$$\underbrace{R\text{-}SO_3\text{-}Na^+}_{\text{SPENT RESIN}} + H_2SO_4 \rightarrow \underbrace{R\text{-}SO_3\text{-}H}_{\text{REGENERATED RESIN}} + Na^+$$

SLIDE #12

be regenerated with sulphuric acid.

Look at slide number thirteen. Anion exchangers are usually high molecular weight polymers with a nitrogen exposed. They work in the same way that cation exchangers work but are recharged with caustic soda.

Advance to slide number fourteen. Ion exchangers used in series produce very pure water but only in small quantities. The periodic recharging does not allow continuous operation and ion exchangers are generally not used for large installations.

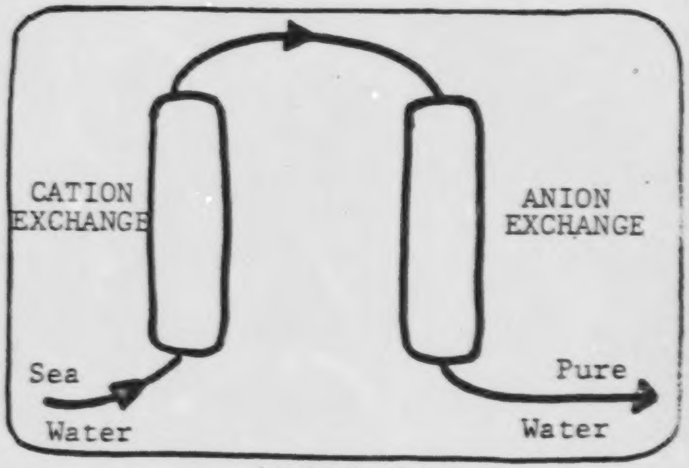
Look at slide number fifteen. Electrodialysis is another way of removing salts from water. The principle is simple. Electrodes attract anions and cations in opposite directions through semipermeable membranes, leaving pure water in the center compartment.

Look at slide number sixteen. Osmosis is the diffusion of water through a differentially permeable membrane from a region of high WATER concentration to a region of low

$\text{P-N-OH} + \text{Cl}^- \text{ --- } \text{P-N-Cl} + \text{OH}^-$

Recharge:
$\text{P-N-Cl} + \text{NaOH} \text{ --- } \text{P-N-OH} + \text{NaCl}$

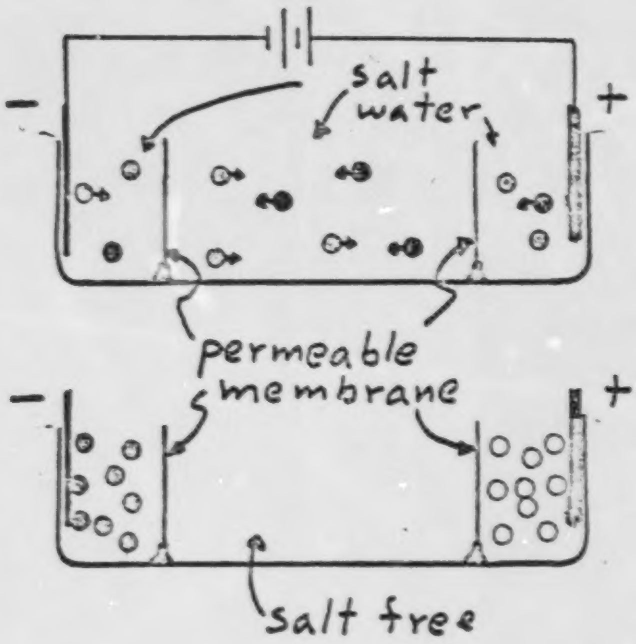
SLIDE #13



SLIDE #14

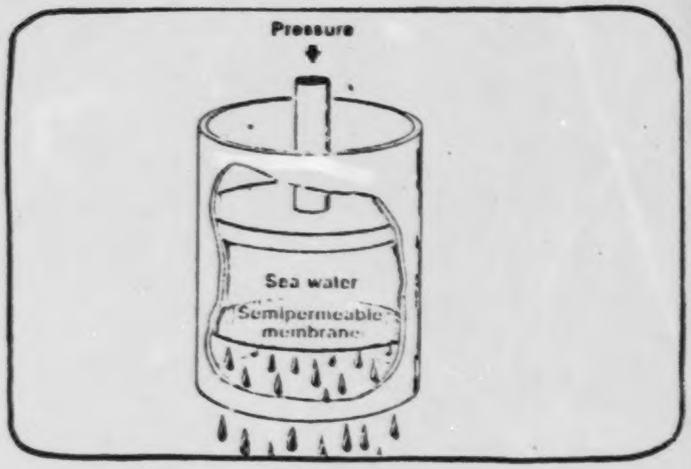
See Page 427A - Following

SLIDE #15


salt water
−
+
permeable membrane
−
+
salt free

SLIDE #15

WATER concentration. Osmotic pressure is the maximum pressure that can be developed in a solution that is separated from pure water by a rigid membrane permeable only to water. If this maximum pressure is exceeded water will flow from the salt solution toward the fresh water. The membrane is used much like a screen to screen ions.



SLIDE #16

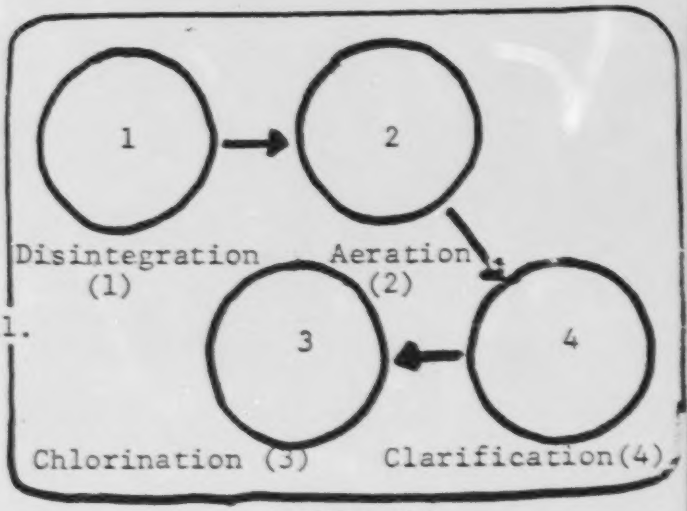
Look at slide number seventeen. Shipboard sewage disposal is becoming a major concern. The pollution of the seas, harbors, rivers, and inland waterways is fast becoming one of the major world problems. As we have discussed before, waters have a self purifying capacity, but not a limitless one.

This slide is a picture of a polluted stream.

SLIDE #17

Sewage is biodegradeable, that is, the action of bacteria can decompose sewage and render it harmless and non-polluting. A sewage disposal system must be designed so that bacteria can do their work.

Look at slide number eighteen. There are four steps to sewage disposal. The first is disintegration, that is, breaking up the solids into fine



SLIDE #18

particles. The second step is aeration so that the bacteria can grow without lowering the biological oxygen demand to a point where they destroy themselves. The third step is clarification, usually a settling process. The last step is chlorination of the clear or supernatant fluid before discharge.

Look at slide number nineteen. Slide number nineteen depicts a diagram of a sewage system for treatment of raw sewage aboard ship. This system is distributed by Drew Chemical Company.

This slide shows a diagram by Drew Chemical Company of a sewage treatment system.

The system includes an aeration tank, and first and second stage clarifiers (settling tank and a Cl_2 contract respectively).

SLIDE #19

Raw sewage comes in at the left and is dumped into a screen basket. The aeration mixing pump causes violent agitation in the aeration tank and the solids are soon battered around in the basket so that they pass through the openings. Bacteria in the aeration tank decompose the sewage.

The mixed liquor transfer pump periodically pumps some of the mixture into a settling tank. After about 70 minutes the supernatant liquor pump transfers the upper portion of the liquor into the chlorine contact tank where it is chlorinated and allowed to stand for about eighty minutes. The sludge return pump in the settling tank returns the sludge to the aeration tank where bacteria continue to act upon it. The small amount of sludge that settles out of the chlorine contact tank is also returned to the aeration tank. The clear chlorinated effluent is discharged overboard.

Again, the basic prinicple is to allow bacteria to decompose the sewage. They must be supplied with air to be kept alive. After the bacteria have decomposed the sewage, the effluent is chlorinated and pumped overboard.

Verbally, or in essay form, you should be able to:

(1) Discuss the classes of pollution sources, and general remedies.

(2) Discuss the principles of water purification, with emphasis on municiple water treatment.

(3) Discuss the principles of shipboard sewage treatment.

SLIDE #20

Now advance to slide number twenty. As a result of studying this module, you should be able to (1) write, in a short essay, a discussion of the classes of pollination, sources, and general remedies for the various kinds of pollution, (2) discuss the principle of water purification, particularly municipal water treatment, and (3) discuss the principles of one system of shipboard sewage treatment.

MODULE E-3 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70%, prior to taking the MODULE E-3 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE E-3 as well as to the completion of the problem set. Those pages are: 4, 68-78, 114-116, 138, 142, 143, 173, 214, 215, 223-225, 239, 242-252, 259, 282-298.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown.

Page	Problems
81	5, 6, 7
241	1

MODULE E - 3 PROBLEM SET SOLUTIONS

Page Problem

81 (5) a. NiS = nickle (II) sulfide

b. NO_2 = nitrogen dioxide

c. PbO_2 = lead (IV) oxide

d. $TiCl_3$ = titanium (III) chloride

e. $CoCl_2$ = cobalt (II) chloride

f. SnF_4 = tin (IV) fluoride

g. CBr_4 = carbon tetrabromide

h $CuCl_2$ = copper (II) chloride

81 (6) a. $Sn(CO_3)_2$ = tin (III) carbonate

b. $CuSO_4$ = copper (II) sulfate

c. $Co(NO_3)_3$ = cobalt (III) nitrate

d. $Pb(CrO_4)_2$ = lead (II) chromate

e. $Ca_3(AsO_4)_2$ = calcium arsenate

f. $KMnO_4$ = potassium permanganate

81 (7) a. K_2HPO_4 = potassium hydrogen phosphate

b. $KHCO_3$ = potassium hydrogen carbonate

c. $K_2C_2O_4$ = potassium oxalate

d. $NaHSO_4$ = sodium hydrogen sulfate

e. $Ca(CH_3CO_2)_2$ = calcium arsenate

f. $(NH_4)_2SO_4$ = amonium sulfate

241 (1) The following compounds are electrolytes:
HNO_3 (nitric acid); $MgCl_2$ (magnesium chloride);
$Pb(CH_3CO_2)_2$ (lead arsenate)

Name ________________________

MODULE E3 - 1 EXAMINATION

1. Discuss how each of the following can be used to purify H_2O:

   a. distillation

   b. ion exchange

   c. electrodialysis

   d. reverse osmosis

2. Discuss the relationship between each of the following and H_2O pollution:

   a. heat

   b. radioactive waste

   c. minerals

   d. plant nutrients

   e. organic chemicals

MODULE E3 - 1 EXAMINATION SOLUTION SET

1. a. Unpure water is distilled. The product which is collected may not be pure, especially if the original sample contains contaminants which boil at less than 100 °C.

   b. Ion exchangers put in H^+ and OH^- ions and at the same time remove unwanted anions and cations.

   c. This is a method of removing salts from water. Electrodes attract anions and cations in opposite directions through semipermeable membranes leaving pure H_2O in a center chamber.

   d. This is the movement of water through a differentially permeable membrane such that water flows in the direction of pure water rather than in the opposite direction.

2. a. The addition of heat changes the environment. The change in environment may mean that the new environment exceeds the biological range of its inhabitants.

   b. Radioactive waste makes water unusable for human consumption. This type of waste may also kill water dwellers and/or cause genetic changes in existing species. A large number of dead organisms in an area will lead to other types of pollution. Further, this type of pollution may severely reduce the economic potential of a given sea region.

   c. The introduction of minerals to water often makes the environment toxic to both the organisms living there and to those who wish to drink the water. Death occurs to the animals living in the area. This is followed by a large increase in bacteria and other organisms which breakdown dead material. The decomposers are oxygen demanding organisms and rapidly depleat the area of necessary O_2 supplies thus causing death to additional numbers of organisms.

   d. Plant nutrients allow large amounts of nitrogen, phosphorus and potassium to find their way to water supplies. The introduction of these nutrients into water cause a rapid increase in plant growth and in the numbers of plants. If the rate at which the plants are eaten is less than the rate at which plants grow and multiply, then the amount of plant material increases as well as do the numbers of oxygen demanding decomposers which are present.

   e. Many organic chemicals are toxic to both man and the organisms which inhabit a given body of water.

Name ______________________

MODULE E3 - 2 EXAMINATION

1. Write a short essay discussing the sources, classes and general remedies of water pollution.

2. Write an essay discussing methods of water purification -- with emphasis on municiple and shipboard.

3. Write an essay discussing shipboard sewage treatment.

MODULE E3 - 2 EXAMINATION SOLUTION SET

1. The sources of pollution are heat, plant nutrients, radioactive materials, minerals, organic chemicals, sewage, sediments, inorganic chemicals, etc.

   The general remedy for all of these types of pollution is to prevent the discharge of the agents into water supplies. Other remedies can be found by consulting MODULE E3 - 1 examination solution set, answer number 1.

2. See MODULE E3 - 1 examination solution set, answer number 1. Many ships carry their fresh water supplies; however, others use various combinations of those methods outlined in E3-1 #1 to obtain fresh water.

3. The following is a list of steps which occur in at least one shipboard sewage treatment scheme.

   a. Raw sewage is screened.

   b. Solids are physically broken down.

   c. Bacteria decompose the sewage in an aeration tank.

   d. The liquor from these processes is chlorinated.

   e. Bacteria continue to break down sludge.

   f. The chlorinated effluent is pumped overboard.

Name ______________________

MODULE E3 - 3 EXAMINATION

1. What is the relationship between oxygen demand and pollution?

2. You are out of drinking water and all that is available is e sea water. What is one possible solution to your dilemma?

3. You test a sample of water from what appears to be an especially dirty area. You find the content E. coli (a common result of fecal contamination). Discuss a possible rectification.

MODULE E3 - 3 EXAMINATION SOLUTION SET

1. As organic matter is added to water, bacterial activity increases lowering the water's oxygen content (oxygen demand increases). The O_2 content continues to drop until the decomposing bacteria die. Then organic material levels increase since water is not being purified by natural processes.

2. Distill some salt water.

3. Build a sewage treatment plant to handle wastes rather than discharging them directly into the water supply.

P. 440

Name ____________________

MODULE E3 - 4 EXAMINATION

1. U. S. Codes make illegal the discharge of raw sewage into the sea. Describe a method by which this situation can be handled on board a ship.

2. Define each of the following:

   a. biodegradation

   b. reverse osmosis

   c. electrodialysis

   d. ion exchange

   e. distillation

   f. heat pollution

   g. oxygen demanding agent

MODULE E3 - 4 EXAMINATION SOLUTION SET

1. The following is a list of steps which occur in at least one shipboard sewage treatment scheme.

   a. Raw sewage is screened.
   b. Solids are physically broken down.
   c. Bacteria decompose the sewage in an aeration tank.
   d. The liquor from these processes is chlorinated.
   e. Bacteria continue to break down sludge.
   f. The chlorinated effluent is pumped overboard.

2. a. This means to breakdown something by biological processes.

   b. This is the movement of water through a differentially permeable membrane such that water flows in the direction of pure water rather than in the opposite direction.

   c. This is a method of removing salts from water. Electrodes attract anions and cations in opposite directions through semipermeable membranes leaving pure H_2O in a center chamber.

   d. Ion exchangers put in H^+ and OH^- ions and at the same time remove unwanted anions and cations.

   e. A process in which liquids are boiled and a fraction collected.

   f. The introduction of a constant supply of heat into an area. The introduction of heat changes the original environment by changing the original heat range which existed.

   g. An agent which requires O_2 in order to carry on its activities.

Name ____________________

MODULE E3 - 5 EXAMINATION

1. A body of water is observed to have many dead fish floating on its surface. Discuss the possible causes of this observation as well as methods of rectification.

2. A sample of H_2O is analyzed and found not to contain the normal population of decomposers. What might be the cause and the effect of this situation?

3. What might the effect of screening be on pollution?

4. Name several industrial pollutants often found in H_2O.

MODULE E3 - 5 EXAMINATION SOLUTION SET

1. The obvious rectification is to perge the water of its killer agents. The situation probably occurred because bacteria, attempting to break down organic wastes, multiplied to the point where insufficient O_2 supplies remained to support fish life.

2. As organic matter is added to water, bacterial activity increases lowering the water's oxygen content (oxygen demand increases). The O_2 content continues to drop until the decomposing bacteria die. Then organic material levels increase since water is not being purified by natural processes.

3. It would remove large solid wastes from the water.

4. The sources of pollution are heat, plant nutrients, radioactive materials, minerals, organic chemicals, sewage, sediments, inorganic chemicals, etc. The general remedy for all of these types of pollution is to prevent the discharge of the agents into water supplies. Other remedies can be found by consulting MODULE E3 - 1 examination solution set, answer number 1.

Name ______________________

MODULE E3 - 6 EXAMINATION

1. Explain the relationship between land errosion and pollution.

2. Explain generally how shipboard evaporators function.

3. Define the following terms:
   a. carry over
   b. biodegradation
   c. osmosis

4. Describe how electrodialysis functions to purify H_2O.

MODULE E3 - 6 EXAMINATION SOLUTION SET

1. Erosion means that many of the plant nutrients used in farming are introduced into the water supply (streams and rivers). Also, reverse osmosis is the movement of water through a differentially permeable membrane such that water flows in the direction of pure water rather than in the opposite direction.

2. The shipboard evaporator is essentially a distillation process.

3. a. Carry over a dissolved species which are carried over in the distillation process.

   b. This means to breakdown something by biological processes.

   c. A process during which a fluid moves through a membrane from an area of higher concentration of the liquid to an area of lower concentration until the concentrations are equal on both sides of the membrane.

4. The introduction of minerals to water often makes the environment toxic to both the organisms living there and to those who wish to drink the water. Death occurs to the animals living in the area. This is followed by a large increase in bacteria and other organisms which break down dead material. The decomposers are oxygen demanding organisms and rapidly depleat the area of necessary O_2 supplies thus causing death to additional numbers of organisms.

Name ______________________

MODULE E3 - 7 EXAMINATION

1. Discuss the relationship between each of the following and H_2O pollution and one possible method by which each can be removed from H_2O:

   a. oxygen demanding agents

   b. infectious agents

   c. plant nutrients

   d. organic chemicals

   e. inorganic chemicals and minerals

   f. heat producing agents

MODULE E3 - 7 EXAMINATION SOLUTION SET

1. a. As organic matter is added to water, bacterial activity increases lowering the water's oxygen content (oxygen demand increases). The O_2 content continues to drop until the decomposing bacteria die. Then organic material levels increase since water is not being purified by natural processes. One possible method of rectification is stop dumping organic agents into the water supply.

   b. Infectious agents will cause infection in those who consume the water. One mode of rectification is to route water through a sewage treatment plant prior to its being exhausted into a body of water. Another preventive measure is to purify the water (by boiling, etc.) prior to drinking it.

   c. Plant nutrients allow large amounts of nitrogen, phosphorus and potassium to find their way to water supplies. The introduction of these nutrients into water cause a rapid increase in plant growth and in the numbers of plants. If the rate at which the plants are eaten is less than the rate at which plants grow and multiply, then the amount of plant material increases as well as do the numbers of oxygen demanding decomposers which are present. One method of partial rectification is to limit the amount of plant nutrients used per unit area of land.

   d. See answer in number 1 of MODULE E3 - 7 examination solution set.

   e. The introduction of minerals to water often makes the environment toxic to both the organisms living there and to those who wish to drink the water. Death occurs to the animals living in the area. This is followed by a large increase in bacteria and other organisms which breakdown dead material. The decomposers are oxygen demanding organisms and rapidly depleat the area of necessary O_2 supplies thus causing death to additional numbers of organisms. A possible method of partial rectification is to run effluent through various precipitation processes prior to exhausting it into a water supply.

   f. The addition of heat changes the environment. The change in environment may mean that the new environment exceeds the biological range of its inhabitants. Heated water could be run through cooling coils prior to discharge.

Name ______________________________

MODULE E3 - 8 EXAMINATION

1. Why might it be necessary to aerate some bodies of water?

2. Identify several polluting agents which may be removed by screening.

3. The bodies of several fishes are analyzed. It is found that the DDT content of the adipose tissue is high. Of what might this finding be indicative?

4. Discuss the principles behind municiple water purification.

MODULE E3 - B EXAMINATION SOLUTION SET

1. Bodies of water which contain large amounts of organic matter (especially when the amount of organic matter is continuously increasing) contain large populations of oxygen demanding bacteria. These organisms rapidly deplete a body of available O_2 supplies. When the O_2 supply is exhausted the decomposing bacteria die. As a result dead organic material accumulates.

2. Wood, cans, plastic materials, solid human waste, etc.

3. Perhaps large amounts of DDT have been used on the insects which attack local plant species. Some of these insects are in the food chain of the fishes which have been inspected. Further, the DDT was probably not effective in killing the insects.

4. The basic principles behind municiple water purification (as it relates to sewage disposal) are:

   a. disintegration -- breaking up solids into fine particles.

   b. aeration -- so that decomposing bacteria will have sufficient oxygen supplies.

   c. clarification -- a settling process.

   d. chlorination -- adding chlorine to the water to be discharged into local bodies of water.

Name ______________________

MODULE E3 - 9 EXAMINATION

1. A sample of drinking water is analyzed and found to have a high content of salt. How can this situation be corrected?

2. Discuss the steps in simple sewage treatment.

3. Define the following terms:
   a. oxygen demand
   b. biodegradable
   c. radioactive pollution

MODULE E3 - 9 EXAMINATION SOLUTION SET

1. By distilling the water prior to drinking it.

2. Basic principles behind municiple water purification (relating to sewage disposal) are:

   a. disintegration -- breaking up solids into fine particles.
   b. aeration -- so that the decomposing bacteria will have sufficient oxygen supplies.
   c. clarification -- a settling process.
   d. chlorination -- adding chlorine to the water to be discharged into local bodies of water.

   The following is a list of steps which occur in at least one shipboard sewage treatment scheme:

   a. raw sewage is screened.
   b. solids are physically broken down.
   c. bacteria decompose the sewage in an aeration tank.
   d. the liquor from these processes is chlorinated.
   e. bacteria continue to break down sludge.
   f. the chlorinated effluent is pumped overboard.

3. a. Oxygen demand is normally the amount of oxygen required to carry on the life processes in a body of water; that is, the amount of oxygen demanded by the organisms in an area.

   b. Something which can be decomposed by biological processes.

   c. Pollution caused by the introduction of radioactive materials into an area. A mutagenic type of pollution.

Name ____________________________

MODULE E3 - 10 EXAMINATION

1. Write a short essay discussing the sources, classes, and general remedies for water pollution.

2. Explain what is meant by ion exchange and how it can be used in water purification.

3. A water sample is analyzed and found to contain several inorganic chemicals. What are two possible sources of these chemicals and how might they be removed from the water supply?

MODULE E3 - 10 EXAMINATION SOLUTION SET

1. The sources of pollution are heat, plant nutrients, radioactive materials, minerals, organic chemicals, sewage, sediments, inorganic chemicals, etc. The general remedy for all of these types of pollution is to prevent the discharge of the agents into water supplies. Other remedies can be found by consulting MODULE E3 - 1 examination solution set, answer number 1.

2. Ion exchangers put in H^+ and OH^- ions and at the same time remove unwanted anions and cations.

3. Plant nutrients, discharge from industry. They might be removed by ion exchange, or reverse osmosis.

HIGH PRESSURE BOILER WATER TREATMENT

Module E4, High Pressure Boiler Water Treatment, is an elective module. As a result of studying this module, the student will be able to discuss and deal with high perssure boiler water treatment.

Now advance your carrousel to slide number one. The term High Pressure Boiler has for years referred to boilers whose normal drum pressure was from 500-850 psig. Boilers whose operating pressure is above 850 psig are referred to as Ultra High Pressure (UHP) boilers. The boilers in most ships constructed today are in the 1200 psig or UHP range. With an increase in pressure and temperature the corrosion processes are accelerated and demand much closer control than was required in the low pressure boiler.

LOW PRESSURE BOILER	500 psig
HIGH PRESSURE BOILER	500 - 850 psig
ULTRA HIGH PRESSURE	850 psig and up

SLIDE #1

Two of the particular problems of ultra high pressure boiler systems are metal oxide deposition and caustic corrosion.

SPECIAL PROBLEMS OF ULTRA HIGH PRESSURE SYSTEMS:

1. METAL OXIDE DEPOSITION
2. CAUSTIC CORROSION

SLIDE #2

Look at slide number two. Metal oxides are often the corrosion product from the condensate system. These finely powdered solids tend to be deposited on those surfaces in the boiler where the heat transfer is the greatest. Obviously, the condenser corrosion effects other parts of the steam system, and while the total surfaces of the condensers are undergoing slight corrosion, all the corrosion products tend to collect in a small area in the boiler.

Advance to slide number three. You recall from the Module C4 that hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine, however, can decompose in the presence of heat to form ammonia and nitrogen. Both are gases, which are carried over and redissolved in the condensate. In the condensers, the dissolved ammonia now forms ammonium hydroxide. The ammonium hydroxide raises the pH of the condensate while the ammonia reacts with the protective cupric oxide coatings of the condenser copper tubing to form extremely soluble copper-ammonium compounds. This adds to the total dissolved solids and causes corrosion of the copper tubing.

$$N_2H_4 \longrightarrow NH_3 + N_2$$

$$NH_3 + H_2O \longrightarrow \underset{\displaystyle NH_4^+ + OH^-}{\underset{\downarrow}{NH_4OH}}$$

SLIDE #3

One of the tests run in the Drew Ultra Marine high pressure boiler treatment program is a test for presence of ammonia in the condensate.

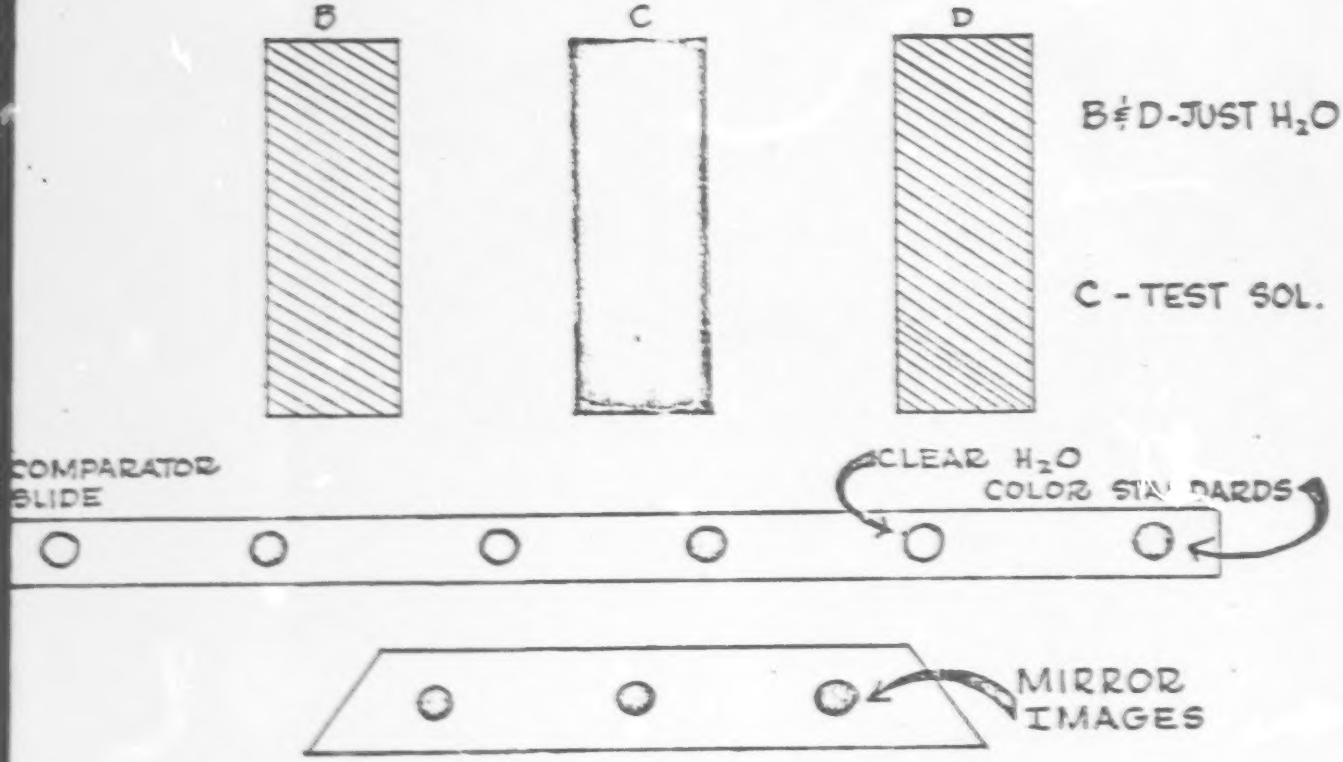
Let's pause in our discussion of high pressure control systems to run the ammonia test.

See Page 456A - Following

SLIDE #4

Look at slide number four. Since this is the first time you will use the water analyzer, let me discuss it for a few minutes. All the tests are colorimetric tests, that is, they are designed to show the concentration of the material being analyzed for in terms of the color, or shade of a color formed in a reaction. The color formed is compared to a set of standard colors contained in a slide. Since some of the colors are so pale and the difference in shades so slight between measured values, we literally amplify the color intensity by having the light we look at pass through a long tube containing the colored solution. These tubes are called Hessler tubes and are fragile, so handle them with care. Since even a long tube of pure water will affect the light passing through it, we must

WATER ANALYZER


B
C
D
B & D - JUST H_2O
C - TEST SOL.
COMPARATOR SLIDE
CLEAR H_2O
COLOR STANDARDS
MIRROR IMAGES

have the light which comes through the standard color ampules also pass through the same length of water in a Nessler tube, but this water is untreated or uncolored.

Look at slide number five. The color of the treated tube is compared to the standard color ampules by looking at their reflected image in the mirror.

See Page 457A - Following

SLIDE #5

Advance to slide number six. The ammonia test is described in the Drew Chemical Co. Ultra Marine Vessel Record Book (see your instructor for this text). Several of the tests described therein are contained in your lab workbooks. Find the instructions for the ammonia test in your lab workbook. Use a water sample from the carboy marked Boiler C for your test.

DREW - ULTRA MARINE

AMMONIA TEST

LIMIT: 0.5 PPM

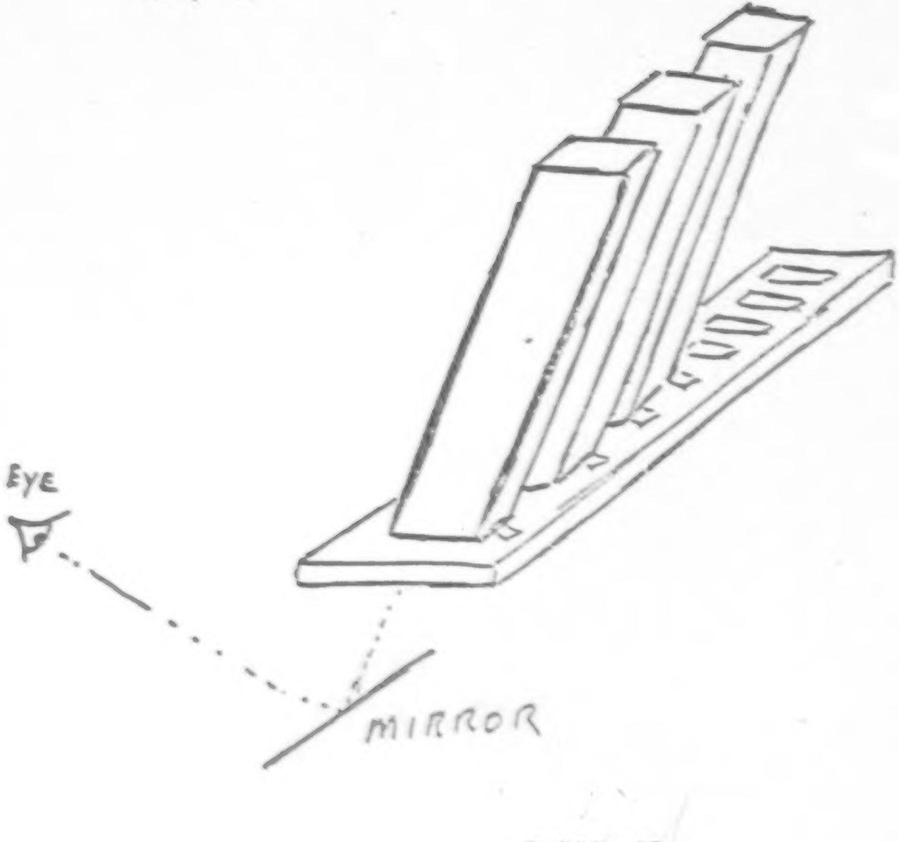
TEST FREQUENCY: WEEKLY

NOTE: USE LONG (250 mm) NESSLER TUBES -- HANDLE WITH CARE

SLIDE #6

You have already run one type of hydrazine test. For high pressure boilers the test is more critical so the test is slightly different, but still quite simple. Turn to the Water Analyzer Hydrazine test in your lab workbook and run the test. Use water

E4-5



SLIDE #5

from the carboy marked Boiler C for your test.

Look at slide number seven. The amount of ammonia present in the condensate can be controlled by adjusting the amount of hydrazine or amerzine used. We can also determine the actual amount of corrosion taking place in the condenser by measuring the amount of copper corrosion products dissolved in the water. Your lab manual contains instructions for running this test. You may run it now or skip it until later or pass it by completely. It is not required that you perform this test, only that you understand why it is performed.

COPPER AND IRON TESTS

USUALLY DONE IN COMMERCIAL LABS

OPTIONAL FOR THIS UNIT

CHEMICALS AND EQUIPMENT AVAILABLE

CHECK WITH INSTRUCTOR IF YOU WISH TO RUN THESE TESTS

SLIDE #7

Look at slide number eight. Here we review some of the basic concepts of corrosion control and scale prevention. If we add phosphates to the boiler water the phosphates unite with the scale forming ions to form non-adhering sludge. We keep the boiler water basic since any acidic solution is most corrosive to metals.

1. ADD PHOSPHATES TO FORM NON-ADHERING SLUDGE
2. KEEP pH BASIC (HIGHER THAN 7)

SLIDE #8

Advance to slide number nine. This is what happens when one of the

$$\underset{\text{TSP}}{Na_3PO_4} + H_2O \rightarrow \underset{\text{DSP}}{Na_2HPO_4} + \underset{\text{Caustic}}{NaOH}$$

SLIDE #9

phosphates we use is dissolved in water. This phosphate, called trisodium phosphate, reacts with the water (in a process called hydrolysis) to form disodium phosphate and sodium hydroxide. These chemicals are sometimes referred to as Co Phos III, Co Phos II and caustic, respectively. This reaction is reversible and obeys LeChatelier's principle.

$$Na_3PO_4 + H_2O \rightleftharpoons NaHPO_4 + NaOH$$

$$\frac{[Na_2HPO_4][NaOH]}{[Na_3PO_4][H_2O]} = K$$

K = equilibrium constant for TSP

SLIDE #10

Look at slide number ten. You recall that when a chemical reaction is in equilibrium the concentration of each of the reactants multiplied together and divided by the concentration of the products multiplied together is a constant. Since each of the concentrations of the substances (represented by the square brackets around the formula of the substance) is constant, any ratio of them is also constant. Accordingly, from the equation for the hydrolysis of trisodium phosphate, we obtain the definition of the equilibrium constant. LeChatelier's principle says that if one of these concentrations should increase or decrease, the reaction will go in a direction such that the value of K remains constant.

Look at slide number eleven. If we increase the concentration of the sodium hydroxide, by adding some caustic disodium phosphate, the value of K could remain constant only if either the DSP concentration decreased, or the TSP concentration increased. The concentration of the water cannot increase. The reason the concentration of the water cannot increase is that we measure concentration in gram molecular weights per liter and the number of gram molecular weights of water in one liter of solution remains constant. If more water is formed in the reaction, the volume increases, but the concentration remains the same.

$$\frac{[Na_2HPO_4][NaOH]}{[Na_3PO_4][H_2O]} = K$$

SLIDE #11

Look at slide number twelve. The concentration of disodium phosphate is always decreasing since the phosphate is combining with the scale forming ions to produce a non-adhering precipitate or sludge. If now we start boiling off the water, consider

$$TSP + H_2O \rightleftharpoons DSP + NOH$$

Some combines with scale forming ions to form non-adhering sludge

SLIDE #12

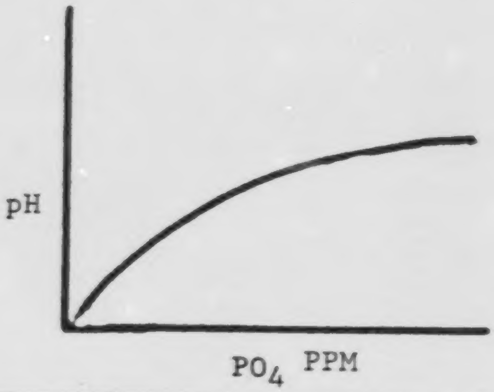
what happens. First the concentrations of all reactants start increasing, but since the reactants in the numerator are multiplied; the numerator increases faster than the denominator. Therefore, the equilibrium must shift to reunite the DSP and the free sodium hydroxide to form TSP.

Look at slide number thirteen. Since some of the DSP has been used up, as the molecules of sodium hydroxide unite with the disodium phosphate to form tridosium phosphate, some of the sodium hydroxide remains free. Then when all of the water has evaporated, all that remains is TSP and free NaOH. It is the free sodium hydroxide which causes severe caustic corrosion in high pressure boilers. If some DSP were added to make up for that lost in scale control, free sodium hydroxide would not be available. When does the boiler water boil down to nothing? The answer is "whenever a drop of water splashes onto a hot dry surface above the water line".

NaOH + DSP → TSP

more molecules   fewer molecules

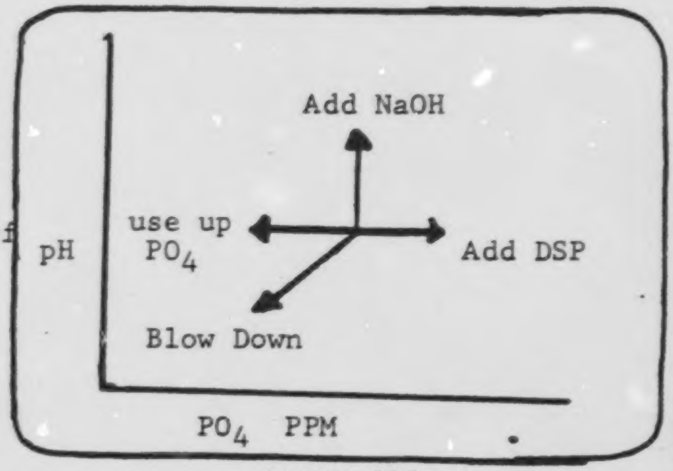
SLIDE #13



SLIDE #14

Look at slide number fourteen. If we add some TSP to water it will hydrolize. forming DSP and NaOH. The formation of NaOH will raise the pH of the water. The presence of PO_4 will increase the PPM concentration of the PO_4.

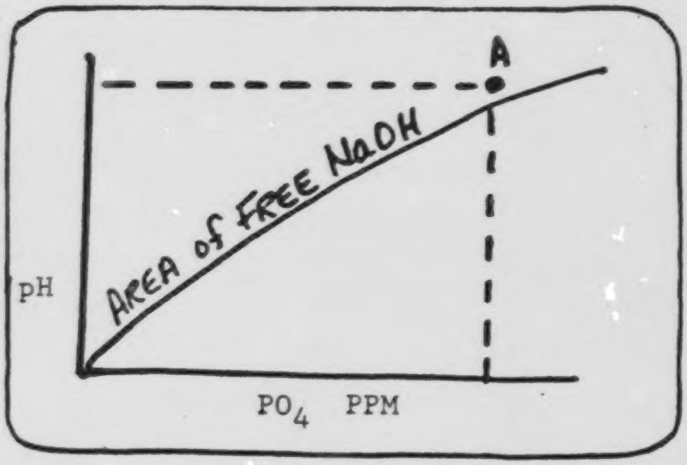
A plot of the pH vs. concentration of PO_4 that results when you add more and more TSP is shown on slide number fourteen. Now, if some of the PO_4 is used in sludge formation the concentration of PO_4 decreases; however, the pH remains constant. If, on the other hand, DSP is added, the concentration of PO_4 increases, but the pH remains constant.



SLIDE #15

Look at slide number fifteen. If the value of pH and PO_4 that results from these actions is plotted, the illustrated results are obtained. Of course, blowdown and replacement with makeup feedwater decreases BOTH the pH and the phosphate concentration.

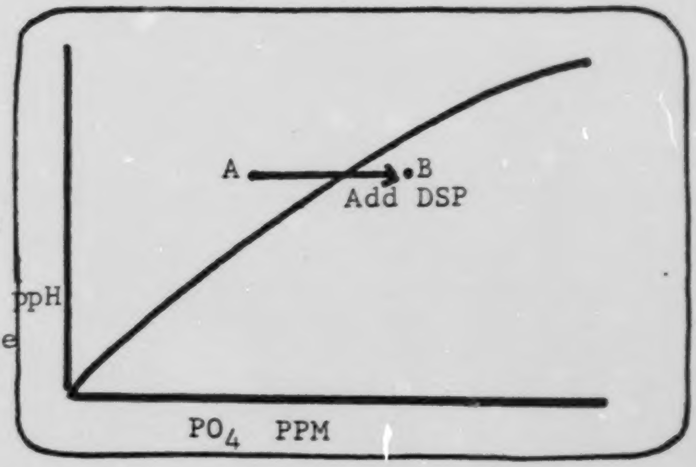
Advance to slide number sixteen. Again we see the plot of phosphate concentration vs. pH for hydrolized TSP. If the pH is above this line for any given concentration of phosphate, it is because there is an



SLIDE #16

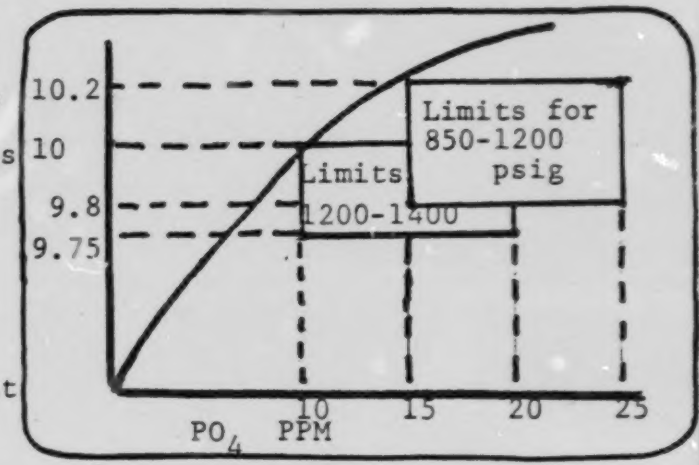
excess of sodium hydroxide in the water. Consequently, the area above the line is called the area of free sodium hydroxide. If we measure the pH of our boiler water and the phosphate concentration and plot the values on a chart, we arrive at the location of point "A", and see that we have free sodium hydroxide in our boiler. This is a potentially dangerous situation. How would you correct the situation?

Look at slide number seventeen. The correct action is to add DSP which would move the point back under the curve. Since the range of pH allowable for the boiler water is limited and since we wish to keep the TDS to a minimum, we find that there are only specific areas on the pH-PO_4 graph where we may allow our boiler water to plot



SLIDE #17

Look at slide number eighteen. The areas outlined are the acceptable areas within which the pH and phosphate concentration may be permitted. A chemical engineering company will examine each high pressure boiler plant and advise specific limits for that plant, but this recommendation will not



SLIDE #18

be far from the values given here. As you can see, the pH range is from 9.8 to 10.2 for 850-1200 psig boilers, a very small range. The range of phosphate is from 15 to 25 ppm, again a narrow range. In order to control the pH and phosphate content it is imperative that we make accurate tests of their values. Let us take a few moments to run through the pH test and the low phosphate test.

Look at slide number nineteen. You have already used the water analyzer in your measurement of ammonia in the condensate. Follow the instructions in your lab manual for pH measurement on page 10 in the Maritec High Pressure Manual. The equipment is shown in slide number nineteen. Run the test several times on water taken from different carboys.

The slide shows a Taylor water analyzer, two graduated eye droppers, one 100 ml graduated cylinder, one tolyl red and one phthalein red color block, one bottle of phthalein red indicator, and one bottle of tolyl red indicator.

SLIDE #19

Look at slide number twenty. This piece of equipment is similar to the water analyzer, but since the colors are more intense you do not need the long tubes. Read and follow the directions in the High Pressure Manual by Maritec, page 9. Be careful in

This slide shows one bottle of dry stannous chloride, one 100 ml graduated cylinder, a low phosphate (0-25 ppm) comparitor block, a bottle of molybdate reagent, and three graduated test tubes.

SLIDE #20

handling the glass tubes. They are both fragile and expensive. Take your sample from the carboy labeled "Boiler B".

Look at slide number twenty-one. There are several parameters we can examine in our boiler water treatment. One set of parameters influences the formation of scale. Another set of parameters influences the rate of corrosion, and some parameters influence both scale formation and corrosion. You have already run chloride tests and made TDS measurements.

CONTROL PARAMETERS

Scale Forming Factors
Chlorides
Silica
T D S

SLIDE #21

Silica is a contaminant in boiler water that can become vaporized under high temperature and pressure and be carried over with the steam, condensing out on the turbine blades. Silica deposits on turbine blades cannot be allowed to occur. The silica content of boiler water is measured using a silica test.

Look at slide number twenty-two. Read page 12 of the Maritec Manual. Then take a water sample from the carboy labeled boiler D and run the test.

The slide shows a Taylor water analyzer, three graduated eye droppers, a stirring rod, a 100 ml graduated cylinder, a glass funnel, a piece of filter paper, a W.A. high silica (0-25 ppm) comparitor block, and three small reagent bottles containing the chemicals necessary to run the test.

SLIDE #22

Now advance to slide number twenty-three. The importance of some tests is reflected in the frequency with which they are required. This chart is from the Drew Chemical Company Ultra Marine High Pressure Boiler Water Treatment Manual. Note the tests which are required twice daily. Examine this chart. Can you perform all the tests listed? The hardness test listed here is different from the soap hardness test you ran in Module D2. This test is quite simple and it is recommended that you run through it once. It is described in the pages for the Drew Ultra Marine System.

See Page 466A - Following

SLIDE #23

Look ~~at~~ slide number twenty-four. Use a sample from the carboy labeled Boiler A and run the test.

The slide shows a 100 ml graduated cylinder, two brass measuring cups, a stirring rod, a 10 ml burette inserted in a 1 liter bottle, a small container for mixing chemicals and two bottles containing the reagents necessary to run the test.

SLIDE #24

Look at slide number twenty-five. The optional tests for this module include the test for copper (the Cu test gives an indication of the extent of condenser corrosion), a test for iron (the test for Fe indicates boiler corrosion), and another type of test for chlorides.

OPTIONAL TESTS

Copper

Iron

Drew H.P. Chloride

SLIDE #25

850-1200 psig

Sample	Limits	Test Frequency	Means Of Adjustment
Boiler Water			
Phosphate	15-25 ppm	twice daily	Adj. B (II)
pH	9.8-10.2	twice daily	GC (I)
Chlorides	16 ppm max.	daily	Blowdown
Conductivity	120 mmh. max.	twice daily	Blowdown
Hydrazine	0.01-0.10 ppm	twice daily	Amerzine (III)
Silica	6 ppm max.	weekly	Blowdown
P. Alkalinity	Ref. (1)	daily	
T. Alkalinity	Ref. (1)	daily	
Condensate			
pH	8.6-9.0	twice daily	SLCC-A (IV)
Ammonia	0.5 ppm max.	weekly	(2)
Feedwater			
Conductivity	Ref. (1)	daily	
Hardness	Nil	weekly	
P. Alkalinity	Ref. (1)	weekly	
T. Alkalinity	Ref. (1)	weekly	

SLIDE #23

Advance to slide number twenty-six. You should be able to perform the tests listed on this slide.

REQUIRED TESTS

1. Low Phosphate
2. Hydrazine - High Pressure
3. Silica
4. Ammonia
5. pH
6. Chloride
7. Alkalinity

SLIDE #26

Look at slide number twenty-seven. Slide number twenty-seven lists the topics with which you should be conversant. You should know what is meant by ammonia corrosion and by caustic corrosion and you should be able to explain the equation for the hydrolysis of TSP. Also, you should be able to explain the origin of free NaOH and what can be done to prevent or correct it and you should be able to discuss the reasons why each test is important. For example, is a test required to control scale or corrosion?

TOPICS TO DISCUSS

1. Ammonia Corrosion
2. Caustic Corrosion
3. Hydrolysis of T S P
4. Free Caustic
5. Importance of Each Test

SLIDE #27

Now look at slide number twenty-eight. You should also review page 84 in the Engineer's Manual of Marine Boiler and Feedwater Treatment, as well as pages 105-112 and 125-127.

REVIEW

Work Book -- High Pressure Tests

Text -- Pages

84   Silica Contamination

105 - 112

125 - 127

SLIDE #28

MODULE E-4 PROBLEM SET

Introduction

The problem set listed below was taken from your course text, Miller, G.H., and Augustine, F.B., Basic Chemistry. Canfield Press: San Francisco, 1975. It must be completed, with a grade of 70% prior to taking the MODULE E-4 examination for the first time. You may submit the problem set as many times as are necessary in order to attain the 70% level.

The following pages in your text are relevant to MODULE E-4 as well as to the completion of the problem set. Those pages are: 46, 64, 76, 84-91, 204-206, 228-240.

Problem Set

The following questions should be answered and submitted to your instructor for evaluation. They should be neatly written and each successive step in the solution should be shown.

Page	Problem
241	4 and 7

MODULE E-4 PROBLEM SET SOLUTIONS

Page	Problem	
241	(4)	$Cu^{2+} + S^{2} \longrightarrow CuS(S)$
241	(7)	Hydronium ion - hydroxide ion. The strongest acid that can exist in any solvent is the conjugate acid of the solvent. The strongest base that can exist is the conjugate base.

Name ______________________________

MODULE E4 - 1 EXAMINATION

1. Write the equation for the hydrolysis of TSP:

2. Which way does the reaction move when I add:

   a. TSP

   b. DSP

   c. NaOH

   d. H_2O

3. Draw a pH-PO_4 plot of the change of the boiler water characteristics for each of the above:

4. Explain what is meant by "free caustic". Where does it come from?

MODULE E4 - 1 EXAMINATION SOLUTION SET

1. TSP + H_2O → DSP + NaOH

2. According to LeChatelier's principle, addition of any reactant or product would cause a shift in one direction or the other as follows:

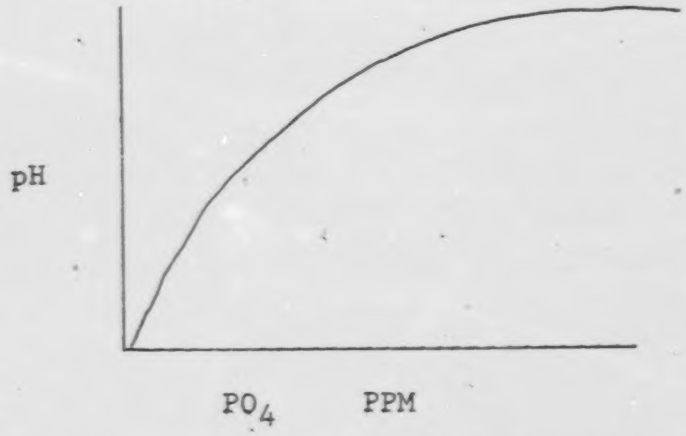
   a. Addition to TSP would cause the system to shift in such a way as to reduce TSP. This means that the equation will shift in the direction of forming more DSP + NaOH.

   b. Addition of DSP will cause the reaction to shift toward TSP + H_2O.

   c. Addition of NaOH will cause a shift toward TSP + H_2O.

   d. Addition of H_2O will cause a shift toward DSP + NaOH.

3.



4. Free caustic means that the pH of the water is above the line on the pH - PO_4 plot. It occurs at any time when there is excess NaOH in the water (it is a potentially dangerous situation).

Name ______________________

MODULE E4 - 2 EXAMINATION

1. Explain the dangers of excess hydrozine in the high pressure boiler:

2. What does an excess of ammonia signify? How can you control this excess?

3. What is a Nissler Tube?

4. What do phosphates do when added to the boiler water?

5. What is LeChatelier Principle? Give an example:

6. What is the purpose of a pH-PO_4 plot?

MODULE E4 - 2 EXAMINATION SOLUTION SET

1. Hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine can decompose in the presence of heat to form ammonia and nitrogen. Both gases are then carried over in the presence of heat and redissolved in the condensate. In the condensers, the dissolved ammonia forms ammonium hydroxide which raises the pH of the condensate. Ammonia reacts with the protective cupric oxide coatings of the condenser tubing to form soluble copper-ammonium compounds thus causing copper corrosion and also adding to the total dissolved solids.

2. See #1 above. Also control the amount of hydrazine used and monitor ammonia content in the condensate with a periodic testing program.

3. A Nessler tube is a long tube which amplifies the color intensity as light passes through it. These tubes are used in colorimetric boiler water tests.

4. The addition of trisodium phosphate (TSP) reacts with water (hydrolysis) to form disodium phosphate (DSP) and NaOH. DSP combines with scale forming ions to produce a non-adhering precipitate or sludge.

5. LeChatelier's principle states that if a system at equilibrium is subjected to a change in conditions that disturbs its equilibrium, the system proceeds toward a new equilibrium state in such a direction as to partially offset the change in conditions. For example, TSP + $H_2O \longrightarrow$ DSP + NaOH.

6. A pH - PO_4 plot gives a quick and ready reference to the pH of water for a given PO_4 concentration.

Name ______________________________

MODULE E4 - 3 EXAMINATION

1. What is meant by the term "High Pressure Boiler"?

2. An analysis of your boiler water shows it to contain silicia. What can be expected to happen to your boiler water under high pressure conditions?

3. Describe caustic corrosion:

4. How is pH related to corrosion?

5. What is LeChatelier's principle?

MODULE E4 - 3 EXAMINATION SOLUTION SET

1. High pressure boiler refers to boilers whose normal drum pressure is from 500-850psig. Boilers operating above 850 psig are referred to as UHP or ultra high pressurr boilers.

2. Under conditions of high temperature and pressure, silica can be expected to vaporize and be carried over with steam, condensing out on turbine blades.

3. Caustic corrosion is corrosion which occurs when there is an excess of NaOH or ammonia present.

   Also, hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine can decompose in the presence of heat to form ammonia and nitrogen. Both gases are then carried over in the presence of heat and redissolved in the condensate. In the condensers, the dissolved ammonia forms ammonium hydroxide which raises the pH of the condensate. Ammonia reacts with the protective cupric oxide coatings of the condenser tubing to form soluble copper-ammonium compounds thus causing copper corrosion and also adding to the total dissolved solids.

4. The pH of the water must be held within narrow limits (9.8 - 10.2 for 850 - 1200 psig boilers). Dropping below or going above this range sets up conditions for acid and caustic corrosion.

5. LeChatelier's principle states that if a system at equilibrium is subjected to a change in conditions that disturbs its equilibrium, the system proceeds toward a new equilibrium state in such a direction as to partially offset the change in conditions. For example, $TSP + H_2O \longrightarrow DSP + NaOH$.

Name ______________________

MODULE E4 - 4 EXAMINATION

1. Two problems are particularly related to Ultra High Pressure boiler systems. What are those problems and how might they be rectified?

2. Upon examining the copper condenser tubes of a UHP boiler you find an excess of copper-ammonium compounds. How might this situation have arisen?

3. Explain how color can be used to show the concentration of some elements.

4. Scale is found on the blades of a turbine in a high pressure boiler. How might this have occurred?

MODULE E4 - 4 EXAMINATION SOLUTION SET

1. Two particular problems of ultra high pressure boiler systems are metal oxide deposition and caustic corrosion. Both can be controlled by proper monitoring and treatment of boiler water.

2. Hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine can decompose in the presence of heat to form ammonia and nitrogen. Both gases are then carreid over in the presence of heat and redissolved in the condensate. In the condensers, the dissolved ammonia forms ammonium hydroxide which raises the pH of the condensate. Ammonia reacts with the protective cupric oxide coatings of the condenser tubing to form soluble copper-ammonium compounds thus causing copper corrosion and also adding to the total dissolved solids.

3. Reagents are added to water samples which react with elements contained therein. The colors which are obtained are then compared with standard colors to determine the condition of the water from which the sample was drawn.

4. Under conditions of high temperature and pressure, silica can be expected to vaporize and be carried over with steam, condensing out on turbine blades.

Name ______________________

MODULE E4 - 5 EXAMINATION

1. Define each of the following:

   a. ammonia corrosion

   b. caustic corrosion

2. Write an equation for the hydrolysis of TSP:

3. How does free NaOH occur in boiler water and how can it be corrected?

4. What is the meaning of free caustic?

MODULE E4 - 5 EXAMINATION SOLUTION SET

1. a. Hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine can decompose in the presence of heat to form ammonia and nitrogen. Both gases are then carried over in the presence of heat and redissolved in the condensate. In the condensers, the dissolved ammonia forms ammonium hydroxide which raises the pH of the condensate. Ammonia reacts with the protective cupric oxide coatings of the condenser tubing to form soluble copper-ammonium compounds thus causing copper corrosion and also adding to the total dissolved solids.

   b. Caustic corrosion is corrosion which occurs when there is an excess of NaOH or ammonia present.

   Also, see solution 1.a. above.

2. $TSP + H_2O \longrightarrow DSP + NaOH$.

3. When the equation shifts or DSP is used up in the presence of excess NaOH, free NaOH remains. The situation could be corrected by adding DSP.

4. Free caustic means that the pH of the water is above the line on the pH - PO_4 plot. It occurs at any time when there is excess NaOH in the water (it is a potentially dangerous situation).

Name ____________________

MODULE E4 - 6 EXAMINATION

1. What are Nessler tubes and what is their relationship to boiler corrosion?

2. An excess amount of ammonia is found in the boiler water condensate. How can this be controlled?

3. What is the relationship between solubility and heat? Further, is there any relationship between these parameters and corrosions in UHP boilers? Explain your answers.

MODULE E4 - 6 EXAMINATION SOLUTION SET

1. A Nessler tube is a long tube which amplifies the color intensity as light passes through it. These tubes are used in colorimetric boiler water tests.

   Reagents are added to water samples which react with elements contained therein. The colors which are obtained are then compared with standard colors to determine the condition of the water from which the sample was drawn.

2. Hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine can decompose in the presence of heat to form ammonia and nitrogen. Both gases are then carried over in the presence of heat and redissolved in the condensate. In the condensers, the dissolved ammonia forms ammonium hydroxide which raises the pH of the condensate. Ammonia reacts with the protective cupric oxide coatings of the condenser tubing to form soluble copper-ammonium compounds thus causing copper corrosion and also adding to the total dissolved solids.

3. As temperature increases, solubility generally tends to increase. That means that as temperature increases, a greater quantity of something may be dissolved per unit volume of H_2O. This suggests that there is a greater chance for carryover thus an increased corrosion hazzard.

Name ______________________

MODULE E4 - 7 EXAMINATION

1. A sample of boiler water is tested using a color responsive test. The color is found to be different from the standard. Explain this finding.

2. The tubes of a boiler are inspected and are found to be covered with a cupric oxide coating. What is the meaning of this finding?

3. Powdered solids are found to be depositing in a certain area of a boiler. What does this information suggest concerning the boiler?

4. What happens when phosphates are added to boiler water?

MODULE E4 - 7 EXAMINATION SOLUTION SET

1. In this case, the standards are shifted until the colors do match. Once the colors have been matched, the concentration is read from the standard and then compared with a chart in order to see how the chemical treatment dosage should be varied (for a given chemical being tested for).

2. Hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine can decompose in the presence of heat to form ammonia and nitrogen. Both gases are then carried over in the presence of heat and redissolved in the condensate. In the condensers, the dissolved ammonia forms ammonium hydroxide which raises the pH of the condensate. Ammonia reacts with the protective cupric oxide coatings of the condenser tubing to form soluble copper-ammonium compounds thus causing copper corrosion and also adding to the total dissolved solids.

3. This is metal oxide deposition. It suggests the occurrence and existence of ongoing corrosion.

4. According to LeChatelier's principle, addition of any reactant or product would cause a shift in one direction of the other as follows:

   a. Addition to TSP would cause the system to shift in such a way as to reduce TSP. This means that the equation will shift in the direction of forming more DSP + NaOH.

   b. Addition of DSP will cause the reaction to shift toward TSP + H_2O.

   c. Addition of NaOH will cause a shift toward TSP + H_2O.

   d. Addition of H_2O will cause a shift toward DSP + NaOH.

   The addition of trisodium phosphate (TSP) reacts with water (Hydrolysis) to form disodium phosphate (DSP) and NaOH. DSP combines with scale forming ions to produce a non-adhering precipitate or sludge.

Name ______________________

MODULE E4 - 8 EXAMINATION

1. Explain how a pH-PO_4 plot can be used in the control of boiler corrosion:

2. When scale forming ions are present in a boiler water sample, why should a chemical be added which forms a precipate?

3. What is the relationship between the following equation and boiler corrosion?

$$\text{TSP} + H_2O \longrightarrow \text{DSP} + \text{NaOH}$$

4. What is the result of blowdown and replacement of makeup feed water?

MODULE E4 - 8 EXAMINATION SOLUTION SET

1. Free caustic means the pH of the water is above the line on the pH - PO_4 plot. It occurs at any time when there is excess NaOH in the water (it is a potentially dangerous situation).

   A pH - PO_4 plot gives a quick and ready reference to the pH of water for a given PO_4 concentration.

2. A chemical should be added to purge the water of these ions. The elimination of these ions will prevent the formation of unwanted scale which results in decreased boiler efficiency.

3. TSP is added to boiler water to yield DSP + NaOH. DSP unites with scale forming agents to produce a non-adhering sludge. However, existence of an improper amount of DSP leads to the existence of free NaOH. Free NaOH leads to corrosion.

4. Blow and replacement with makeup feedwater decreases both phosphate and concentration and pH.

Name ______________________

MODULE E4 - 9 EXAMINATION

1. Explain the relationship between pressure and boiler errosion:

2. In the following equation, TSP + $H_2O \rightleftharpoons$ DSP + NaOH, which way would you expect the equation to move if each of the following were added, one at a time:

   a. H_2O

   b. NaOH

   c. DSP

3. Explain LeChatelier's principle.

4. How is a Nessler tube used?

MODULE E4 - 9 EXAMINATION SOLUTION SET

1. The higher the pressure the more accelerated the corrosion processes become. This means that high pressure boilers demand closer corrosion control than do lower pressure boilers.

2. a. Addition of H_2O will cause a shift toward DSP + NaOH.

   b. Addition of NaOH will cause a shift toward TSP + H_2O.

   c. Addition of DSP will cause the reaction to shift toward TSP + H_2O.

3. LeChatelier's principle states that if a system at equilibrium is subjected to a change in conditions that disturbs its equilibrium, the system proceeds toward a new equilibrium state in such a direction as to partially offset the change in conditions. For example, TSP + H_2O $\longrightarrow$ DSP + NaOH.

4. A Nessler tube is a long tube which amplifies the color intensity as light passes through it. These tubes are used in colorimetric boiler water tests.

Module E4
P. 488

Name ____________________

MODULE E4 - 10 EXAMINATION

1. Identify several causes of corrosion in high pressure and ultra high pressure boilers, their modes of actions, and methods of preventing them.

2. What liability is incurred when hydrazine is added to boiler feedwater?

3. Deposits are found on turbine blades. How could this happen?

4. What is the relationship between equilibrium constants and corrosion?

MODULE E4 - 10 EXAMINATION SOLUTION SET

1. Three causes of corrosion in HP and UHP boilers are:

   (1) Use of excess hydrazine; (2) the existence of excess DSP; and (3) carryover of silica.

   They all can be prevented by proper boiler water monitoring and treatment.

   For their modes of action see examination solution sets for the following:

   E4 - 2 #1
   E4 - 3 #2
   E4 - 5 #3
   E4 - 6 #3
   E4 - 8 #3

2. Hydrazine reacts with oxygen to form water and nitrogen gas. Excess hydrazine can decompose in the presence of heat to form ammonia and nitrogen. Both gases are then carried over in the presence of heat and redissolved in the condensate. In the condensers, the dissolved ammonia forms ammonium hydroxide which raises the pH of the condensate. Ammonia reacts with the protective cupric oxide coatings of the condenser tubing to form soluble copper-ammonium compounds thus causing copper corrosion and also adding to the total dissolved solids.

3. Under conditions of high temperature and pressure, silica can be expected to vaporize and be carried over with steam, condensing out on turbine blades.

4. LeChatelier's principle states that if a system at equilibrium is subjected to a change in conditions that disturbs its equilibrium, the system proceeds toward a new equilibrium state in such a direction as to partially offset the charge in conditions. For example, TSP + H_2O --- DSP + NaOH.

   According to LeChatelier's principle, addition of any reactant or product would cause a shift in one direction or the other as follows:

   > Addition to TSP would cause the system to shift in such a way as to reduce TSP. This means that the equation will shift in the direction of forming more DSP + NaOH.
   >
   > Addition of DSP will cause the reaction to shift toward TSP + H_2O.
   >
   > Addition of NaOH will cause a shift toward TSP + H_2O.
   >
   > Addition of H_2O will cause a shift toward DSP + NaOH.

   When the equation shifts or DSP is used up in the presence of excess NaOH, free NaOH remains. The situation could be corrected by adding DSP.

METRIC SYSTEM

The R Modules are designed to aid students who are having difficulties with mathematics, especially those areas of mathematics which the student must rely upon in order to solve problems related to his or her study of chemistry.

Module R1, Metric System, is the first of five R Modules.

Advance your carrousel to slide number one. To describe something accurately we must be able to measure it. This requires a system of measurement. A system of measurement must have defined units for determining length, mass, electric charge and time. The physical universe and its contents can be described in terms of these four parameters.

Measurement of	Metric Unit	English Unit
length	meter	foot
mass	gram	slug
electric charge	coulomb	coulomb
time	second	second

SLIDE #1

Now advance to slide number two. Area and volume are derived from length by squaring it and cubing it respectively Liquid volume is derived from density and mass ($V = M/D$). One gram is the mass of 1/1000 of a liter of water, or is the mass of one millionth of a

Measurement	Unit	Description
Length	Meter	About a yard
Area	Square Meter	Length^2
Volume	Cubic Meter	Length^3
Liquid Volume	Liter	1000 grams water occupies one liter
Mass	Gram	the mass of one cubic centimeter of water

SLIDE #2

cubic meter of water. One liter is the volume occupied by 1000 grams of water or is 1/1000 of a cubic meter. A liter is about one quart in the English system.

Look at slide number three. Multiple and proportional parts of basic units are powers of ten in the metric system. The four listed on slide number three are the ones you are most apt to use in chemistry. They are used as prefixes to multiply the basic unit to which they are attached.

Multiples and Proportional Parts:

Prefix	Value	
Micro	$\frac{1}{1,000,000}$	one millionth
Milli	$\frac{1}{1,000}$	one thousandth
Centi	$\frac{1}{100}$	one hundredth
Kilo	1,000	one thousand times

SLIDE #3

Look at slide number four. A milliliter is 1/1000 of a liter, a milligram is 1/1000 of a gram, a centimeter is 1/100 of a meter, and so on. Some common units and their English equivalents are listed on slide number four. A kilometer is about half a mile. A meter is about a yard. The 100 meter dash is slightly longer than the hundred yard dash. A centimeter is about half an inch. A kilogram is about two pounds. A liter is about a quart. There are 454 grams in a pound.

See Page 491A - Following

SLIDE #4

The last two lines illustrate a most useful relationship among mass,

UNIT	ABBREVIATION	ENGLISH EQUIVALENT
1 kilometer (1000 meters)	km	.621 miles
1 meter (100 centimeters)	m	39.4 inches
1 centimeter (10 millimeters)	cm	.4 inches
1 kilogram (1000 grams	kg	2.2 pounds
1 liter (1000 milliters, ml)	l	1.06 quarts
1 gram (1000 milligrams)	g	.035 ounces

for WATER: 1 gram = 1 milliliter = 1 cubic centimeter

1 g = 1 ml = 1 cc

SLIDE #4

density and volume. The relationship could not be simpler than 1 to 1 to 1. There is nothing like it in the English system.

Now advance to slide number five. To gain some first hand knowledge about the metric system, obtain a meter stick, a balance, a large graduated cylinder or graduated beaker and a measuring cup for English units. Also, obtain a sheet of standard notebook paper (8½ x 11 inches).

The slide shows a meter stick, a balance, a large 100 ml graduated cylinder, and a cup graduated in English units (oz., etc.)

SLIDE #5

Look at slide number six. Take a sheet of paper and set it up as on slide number six. Weigh the graduated cylinder or beaker and then put 2 cups of water in it. Note the volume of 2 cups of water in both English and metric units. Then weigh the two cups of water in the graduated cylinder or beaker. Remember to subtract the weight of the cylinder or beaker. Also, remember that 2 cups equals 1 pint and a pint is a pound. Now, calculate the number of grams in one pound. You should have found one pound to be equivalent to about 450 grams.

weight of graduated cylinder (Beaker) ____________ g
volume of 2 cups water (Metric) ____________ ml
volume of 2 cups of water (English) ____________pints
weight of 2 cups of water (English) ____________ lbs
weight of 2 cups of water (Metric) ____________ g
(Be sure to subtract the weight of the cylinder or beaker)
Approximately ________ grams of water = 1 lb.

SLIDE #6

Now advance to slide number seven.

Look at slide number eight. Take a meter stick and measure the length and width of an 8½ by 11 inch sheet of paper and record your measurements as indicated on slide number eight. You should have obtained answers somewhere near the following values: 11 inches is 27.9 cm, .279 meters and 279 mm; 8½ inches is 21.6 cm, .216 meters, and 216 mm; the area is 603 square cm. The conversion of inches to cm is 2.54. You should have gotten about 2.5 cm per inch.

The metric system is really simpler than the English system. You will become more at ease with it as you use it. Again, you must have the contents of slides two and three memorized.

The slide shows a person obtaining the metric dimensions of an 8 x 11½ sheet of paper.

SLIDE #7

11" = _____cm = _____m = _____ mm (millimeters)

8½" = _____cm = _____m = _____mm

A = length X width = (_____cm)(_____cm) = _____cm^2

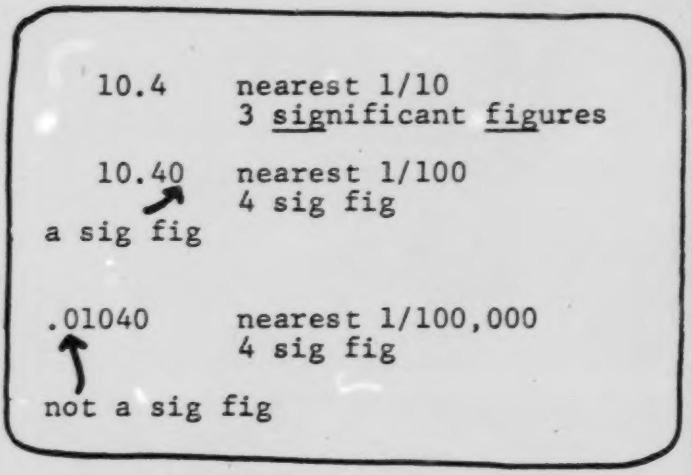
1 inch = _____cm/11" = _____cm/inch

SLIDE #8

SIGNIFICANT FIGURES AND ROUNDING

Module R2, Significant Figures and Rounding, is the second in the R series modules.

Now advance your slide carrousel to slide number one. Any measurement is only an approximation because no measuring device is absolutely perfect. If the weight of an object is given as 10.4 grams, this indicates that the weight of the object was determined accurately to the nearest tenth gram. 10.40 indicates an accuracy to the nearest hundredth gram, and so on. The number 10.4 contains 3 significant figures (1, 0 and 4); 10.40 contains 4 significant figures.



10.4 nearest 1/10
3 significant figures

10.40 nearest 1/100
4 sig fig
a sig fig

.01040 nearest 1/100,000
4 sig fig
not a sig fig

SLIDE #1

A significant figure is one that is known to be reasonably reliable. Zeros which appear in front of a number are not significant figures, but are place holders. Zeros after a number usually are significant figures; however, with large numbers they are sometimes place holders.

0.066	2 sig fig
240.	3 sig fig
0.008732	?
7.07381	?
0.000001	?

SLIDE #2

Look at slide number two. .006 has two significant figures. 240. has

3 significant figures. Try the remaining 3 examples on a piece of paper. .008732 has 4; 7.07381 has 6; and .000,001 has one. Remember that zeros before a number are only place holders.

Advance to slide number three. The following are rules for rounding of off numbers:

1. When the number dropped is less than 5, the preceding number remains the same. 5.34 rounded off becomes 5.3
2. When the number dropped is more than 5, 1 is added to the preceding number. 5.36 becomes 5.4
3. When the number dropped is exactly 5, if the preceding number is even, it remains unchanged; if the preceding number is odd, one is added. 5.45 becomes 5.4; 5.15 becomes 5.2.

On a piece of paper try the 3 remaining examples on slide number three.

Now advance to slide number four. Here you will find the answers which you should have obtained from working the problems on slide number three.

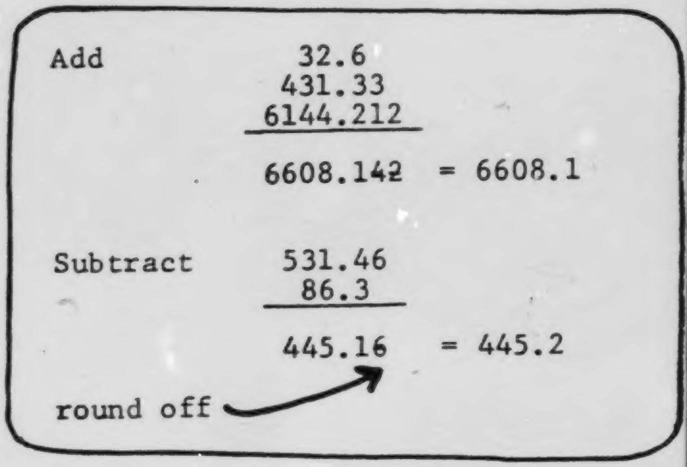
Look at slide number five. When adding or subtracting, the answer should be rounded off so as to be no more accurate than the least accurately

Number	Rounded Off One Place
5.34	5.3
5.36	5.4
5.45	5.4
5.15	5.2
27.1	____
.0738	____
1005.5	____

SLIDE #3

Number	Rounded Off One Place
27.1	27
.0738	.074
1005.5	1006.

SLIDE #4



Add 32.6
431.33
6144.212

6608.142 = 6608.1

Subtract 531.46
86.3

445.16 = 445.2

round off

SLIDE #5

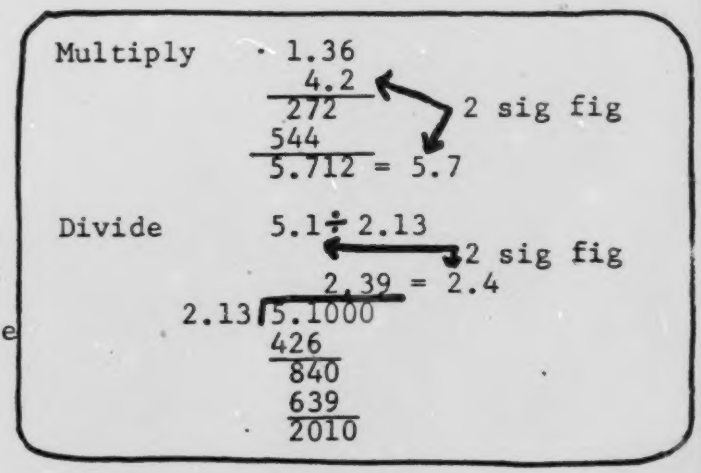
known figure. In both cases, the least accurate figures in one tenth. The final answer can be no more accurate than 1/10.

Look at slide number six. When multiplying or dividing, the answer should be rounded off so as to contain only as many significant figures as are contained in the number having the least number of significant figures.

In both cases, the number containing the least number of significant figures contains 2 significant figures. The answer can contain only 2 significant figures.

Advance to slide number seven. It contains 4 simple problems. Do them and compare your answers to those on the tape after the pause.

The answer to the addition problem is 3.35; the subtraction, 16.7; the multiplication is 3; and the division is 25.



Multiply

$$\begin{array}{r} 1.36 \\ \underline{4.2} \\ 272 \\ \underline{544} \\ 5.712 = 5.7 \end{array}$$

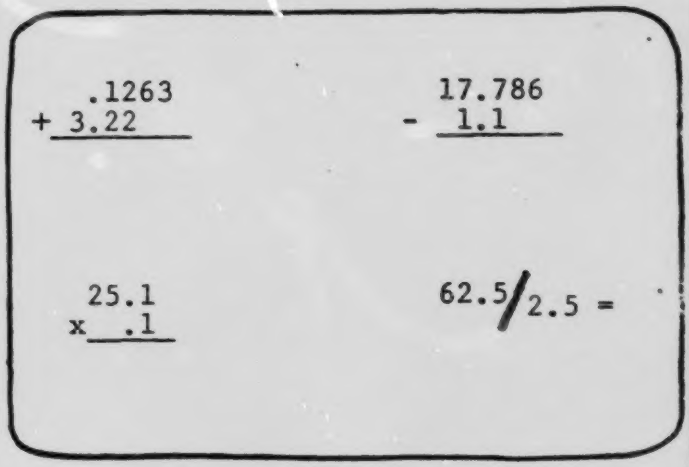
2 sig fig

Divide 5.1 ÷ 2.13

2 sig fig

$$\begin{array}{r} 2.39 = 2.4 \\ 2.13\overline{)5.1000} \\ \underline{426} \\ 840 \\ \underline{639} \\ 2010 \end{array}$$

SLIDE #6



$$\begin{array}{r} .1263 \\ +\ \underline{3.22} \end{array} \qquad \begin{array}{r} 17.786 \\ -\ \underline{1.1} \end{array}$$

$$\begin{array}{r} 25.1 \\ \times\ \underline{.1} \end{array} \qquad 62.5/2.5 =$$

SLIDE #7

SCIENTIFIC NOTATION-EXPONENTIAL [illegible]M

Module R3, Scientific Notation-Exponential Form is the third in the series of five self-help modules.

Advance your carrousel to slide number one. Very large and very small numbers should be expressed in exponential form. These large and small numbers are expressed as 10 raised to some power.

$$\underbrace{10 \times 10}_{\text{twice}} = 100 = 10^2 \leftarrow \text{power or exponent}$$

$$\underbrace{10 \times 10 \times 10}_{\text{three times}} = 1000 = 10^3$$

SLIDE #1

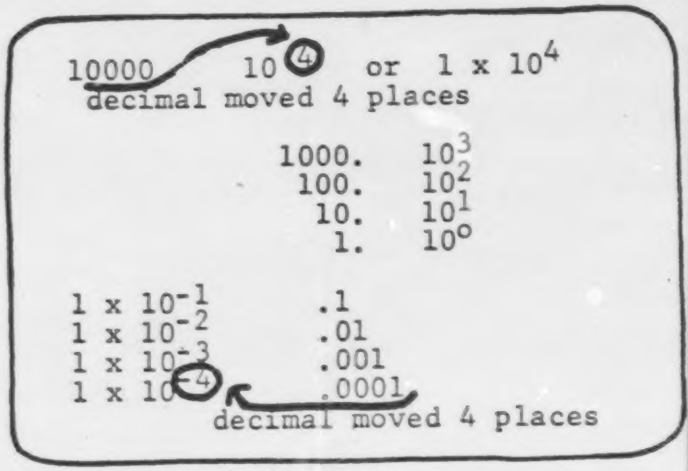
A power, that is, the exponent, indicates how many times a number is repeated as a factor. For example, 10 x 10 which is 10 repeated as a factor twice, is 100 or 10 to the second power, 10 x 10 x 10 is 1000 or 10 to the 3rd power, and so on.

$$10^{-1} = 1/10^{+1} = .1$$

$$10^{-3} = 1/10^3 = 1/1000 = .001$$

SLIDE #2

Look at slide number two. A number with a negative exponent is the reciprocal of that number with a positive exponent. 10 to the -1 power is 1 over 10 to the +1 power; 10^{-3} power is 1 over 10^{+3} power or 1 over 1000.



10000 $\quad 10^{④}$ or 1×10^4

decimal moved 4 places

1000. $\quad 10^3$

100. $\quad 10^2$

10. $\quad 10^1$

1. $\quad 10^0$

1×10^{-1} $\quad$ .1

1×10^{-2} $\quad$ .01

1×10^{-3} $\quad$ .001

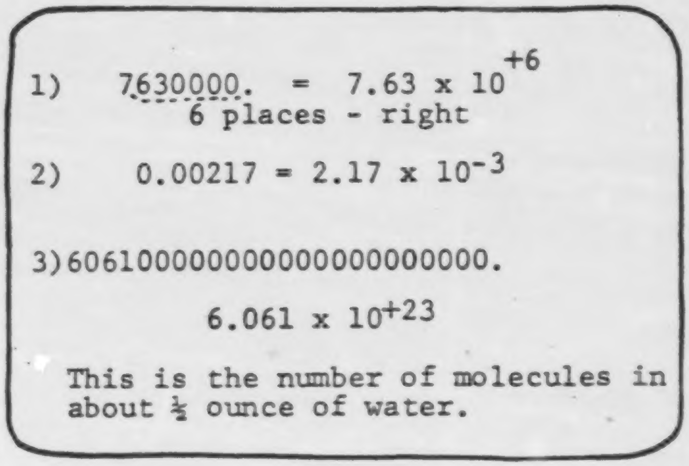
$1 \times 10^{\boxed{-4}}$ $\quad$ .0001

decimal moved 4 places

SLIDE #3

Advance to slide number three. First, note that 10 to the zero power is 1. Any number to the zero power is 1. Second, note that the power is equal to the number of decimal places that the decimal point is moved from 1, with a positive (+) exponent indicating a move to the right and a negative (-) exponent indicating a move to the left.

Look at slide number four. The 3 examples are worked for you. The trick is to write the numbers as a number between 1 and 10 times 10 to some power. The "some power" becomes the number of places the decimal was moved and its sign, the direction.



1) $7630000. = 7.63 \times 10^{+6}$
6 places - right

2) $0.00217 = 2.17 \times 10^{-3}$

3) $606100000000000000000000.$
$6.061 \times 10^{+23}$

This is the number of molecules in about ½ ounce of water.

SLIDE #4

In this first example, the decimal was moved 6 places to the right from a number between 1 and 10, therefore the exponent is +6. In the second example, the decimal is 3 places to the left of where it would be if the number were a number between 1 and 10; therefore, 10 to the minus 3 power. In the third example, the decimal was moved 23 places. This number, incidentally, is known as the Avagadro number. You may run into it again.

Look at slide number five. Convert these numbers into exponential or scientific notation form, as it is sometimes called.

1) 314159.

2) .00000666

3) 96500

4) .0000000000000000000000000000091

SLIDE #5

Look at slide number six. The answers to the problems posed on slide number five are presented here.

1) 314159. = $3.14159 \times 10^{+5}$

2) .00000666 = 6.66×10^{6}

3) 96500 = $9.65 \times 10^{+4}$

4) .0000000000000000000000000000091 = 9.1×10^{-28}

SLIDE #6

Advance to slide number seven. Exponential numbers may be added or subtracted only if the powers of 10 are the same. If the numbers have different powers, the powers must first be equalized by shifting the decimal of one of them. Try the examples which are presented here.

$(5 \times 10^3) + (2 \times 10^3) = 7 \times 10^3$

$(5 \times 10^3) + (2 \times 10^2) = ?$ change either exponent

$(50\times10^2) + (2\times10^2)=52 \times 10^2 = 5200$

$(5 \times 10^3)+(.2 \times 10^3)=5.2 \times 10^3=5200$

TRY THIS ONE:

$(7 \times 10^1) + (5 \times 10^{-2}) = ?$

SLIDE #7

Look at slide number eight. Slide eight contains the answers to the problems posed on slide number seven.

Advance to slide number nine. When multiplying numbers in scientific notation form, multiply the numbers and add the powers of 10.

3×10^4 times 2×10^6 equals 3×2, or 6×10 to the 4 + 6 power.

5×10^{-7} times $3 \times 10^{+2}$ equals 15×10^{-5}. This can be converted to 1.5×10^{-4}.

Look at slide number ten. Try the problems which are presented here.

$(7 \times 10^{1}) + (5 \times 10^{-2})$

Rewrite:

$(7 \times 10^{1}) + (.005 \times 10^{1}) = 7.005 \times 10^{1}$

the difference between -2 and +1 is 3

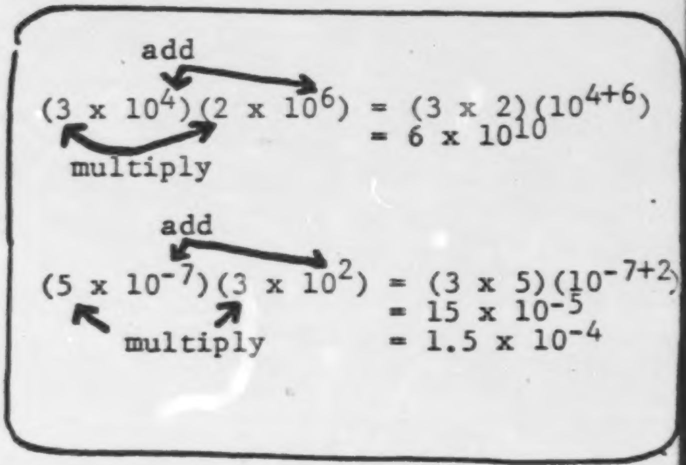
70.05

CHECK: $7 \times 10^{1} = 70.$

$5 \times 10^{-2} = .05$

70.05

SLIDE #8



add

$(3 \times 10^{4})(2 \times 10^{6}) = (3 \times 2)(10^{4+6})$

$= 6 \times 10^{10}$

multiply

add

$(5 \times 10^{-7})(3 \times 10^{2}) = (3 \times 5)(10^{-7+2})$

$= 15 \times 10^{-5}$

$= 1.5 \times 10^{-4}$

multiply

SLIDE #9

$(1.8 \times 10^{4})(7.3 \times 10^{-6}) =$

$(3.14 \times 10^{-1})(2.0 \times 10^{7}) =$

$(8.2 \times 10^{-1})(5.0 \times 10^{-4}) =$

$(6 \times 10^{2})(4 \times 10^{5})(3 \times 10^{-8}) =$

SLIDE #10

Now advance to slide number eleven. Here you will find the answers to the problems from slide ten.

Advance to slide number twelve. When dividing numbers in scientific notation form, divide the numbers and subtract the exponents. The exponent of the denominator is subtracted from the the exponent of the numerator. Ten to the 5th power divided by 10 to the 3rd power becomes 10 to the 5 minus 3 or 10 squared. The second one is done in a similar fashion.

$(1.8\text{x}10^{-4})(7.3\text{x}10^{-6}) = \underline{5.84\text{x}10^{-2}}$

$(3.14\text{x}10^{-1})(2.0\text{x}10^{7}) = \underline{5.28\text{x}10^{6}}$

$(8.2\text{x}10^{-1})(5.0\text{x}10^{-4}) = 41 \times 10^{-5}$
$\underline{4.1 \times 10^{-4}}$

$(6\text{x}10^{2})(4\text{x}10^{5})(3\text{x}10^{-8}) = 72 \times 10^{-1}$
$= 7.2 \times 10^{0}$
$= \underline{7.2}$

SLIDE #11

Look at slide number thirteen. Try these problems.

Now advance to slide number fourteen. Here you will find the answers to the problems from slide thirteen.

$1 \times 10^{5} \div 1 \times 10^{3} = \dfrac{.1 \times 10^{5}}{1 \times 10^{3}}$
$= (1/1) \times 10^{5-3}$
$= 1 \times 10^{2}$

numerator ↓

$\dfrac{6.8 \times 10^{-4}}{1.7 \times 10^{3}} = \dfrac{6.8}{1.7} \times 10^{-4-(+3)}$

↑ denominator $= 4.0 \times 10^{-7}$

SLIDE #12

Look at slide number fifteen. Here is a problem involving both multiplication and division. The problem is done by multiplying and dividing the numbers as though the tens to various powers were not there and then subtracting the sum of the powers in the denominator from the sum of the powers in the numerator.

Now look at slide number sixteen.

Advance to slide number seventeen.

1) $7.7 \times 10^{+3} \div 5 \times 10^{-1} =$

2) $\dfrac{9.6 \times 10^{-7}}{5.0 \times 10^{-7}} =$

3) $\dfrac{4.8 \times 10^{-4}}{5.0 \times 10^{+3}} =$

SLIDE #13

1) $7.7 \times 10^{+3} \quad 5 \times 10^{-1} = \underline{1.54\text{x}10^{+4}}$

2) $\dfrac{9.6 \times 10^{-7}}{5.0 \times 10^{-7}} = \underline{1.92 \times 10^{-14}}$

3) $\dfrac{4.8 \times 10^{-4}}{5.0 \times 10^{+3}} = \underline{9.6 \times 10^{-7}}$

SLIDE #14

$$\frac{(2 \times 10^3)(7 \times 10^5)(4 \times 10^7)}{(3 \times 10^6)(5 \times 10^8)} =$$

$$\frac{2(7)4}{3(5)} \times 10^{3+5+7-(6+8)} =$$

$$\frac{56}{15} \times 10^{15-(+14)} =$$

$$\underline{\underline{3.7 \times 10^{-1}}}$$

SLIDE #15

$$\frac{(8 \times 10^3)(6 \times 10^4)(2 \times 10^5)}{(3 \times 10^6)(4 \times 10^7)} =$$

SLIDE #16

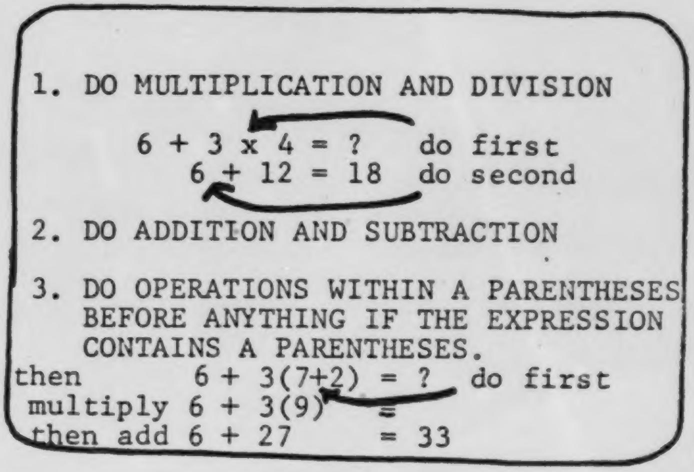
$$\underline{\underline{8 \times 10^{-1}}}$$

SLIDE #17

ALGEBRAIC OPERATIONS

Module R4, Algebraic Operations, is the fourth of five self-help modules.

Advance your slide carrousel to slide number one. It is assumed that you have had a course in algebra sometime in the past. The intent of this unit is to briefly review some of the most fundamental operations. A parenthesis around terms means they are to be multiplied. The order of operations in evaluating terms is to do the multiplication and division first in the order in which they appear. Then do the addition and subtraction. If a parenthesis is involved, do the operation within the parenthesis first.



1. DO MULTIPLICATION AND DIVISION

6 + 3 x 4 = ?   do first
6 + 12 = 18   do second

2. DO ADDITION AND SUBTRACTION

3. DO OPERATIONS WITHIN A PARENTHESES BEFORE ANYTHING IF THE EXPRESSION CONTAINS A PARENTHESES.

then 6 + 3(7+2) = ?   do first
multiply 6 + 3(9) =
then add 6 + 27 = 33

SLIDE #1

Looking at the example under three, the operation, which happens to be addition, comes first; then multiplication, then the addition.

Look at slide number two. Work the four sample problems which are on the slide.

1. 2 + 6(7) = _____
2. 6 - 4/12 + 4(1/3) = _____
3. 3(7 - 18/36 x 2) +1 = _____
4. 2(A + 3/2A) - 3A = _____

SLIDE #2

The answer to problem 1 is 44; problem 2 is 7; problem 3 is 19; and problem 4 is 2a. Problem 4 can be done two ways.

Look at slide number three. The top illustration uses the rules we have discussed. The bottom illustration makes use of the distributive property of multiplication with respect to addition.

$2(A + 3/2A) - 3A = \_\_\_\_\_$
$2(5/2A) - 3A =$
$10/2A - 3A = 5A - 3A = \underline{\underline{2A}}$

THE PROBLEM USING THE DISTRIBUTIVE PROPERTY OF MULTIPLICATION:

$2(A + 3/2A) - 3A = \_\_\_\_\_$
$2A + 2(3)/2A - 3A = \_\_\_\_\_$
$2A + 6/2A - 3A = \_\_\_\_\_$
$2A = 3A - 3A = \underline{\underline{2A}}$

SLIDE #3

An equation is a statement that two sets of things are the same, that one can replace the other, or that they are identical. For example, 2 + 2 will replace 4, or be the same as 4; so we can write that 2 + 2 = 4.

Look at slide number four. The same number may be added to both sides of an equation without destroying the identity. The same is true with subtraction. Notice that in the last illustration, the b's drop out.

THE SAME NUMBER MAY BE ADDED TO BOTH SIDES OF AN EQUATION:

$$3(2) + 4 + 7 = 3(2) + 4 + 7$$

THE SAME NUMBER MAY BE SUBTRACTED FROM BOTH SIDES OF AN EQUATION:

$$3(2) + 4 - 7 = 3(2) + 4 - 7$$

or $AX + B = 1/3A + 2/3A + B$
$AX + B - B = 1/3A + 2/3A + B - B$

SLIDE #4

Advance to slide number five. Each side may be multiplied or divided by the same number without destroying the identity. However, multiplication and division, unlike addition or subtraction are distributive over the entire equation. Whatever number is used to multiply or divide, it becomes the coefficient of every term in the equation.

EACH SIDE OF AN EQUATION MAY BE MULTIPLIED (OR DIVIDED) BY THE SAME NUMBER:

EQUATION: $2X - 1 = 3X$
MULTIPLY BY A: $2AX - A(1) = 3AX$
EQUATION:
$AX + BY + 7 = CX + Y$
DIVIDED BY 2:
$\frac{1}{2}AX + \frac{1}{2}BY + \frac{1}{2}(7) = \frac{1}{2}CX + \frac{1}{2}Y$

SLIDE #5

To solve an equation means to find the number that, when substituted into the equation for the unknown, makes the equation a true statement. The way this number, or root, is found is by isolating the unknown on one side of the equation and placing everything else on the other.

Look at slide number six. The first step in solving the equation is to collect terms. Do all the adding, subtracting, multiplying and dividing that can be done. Then perform inverse operations so that the isolation of the unknown takes place.

$$4X + 2(6+2) + 3X = 5X + 32$$

COLLECT TERMS:

$$7X + 16 = 5X + 32$$

PERFORM INVERSE OPERATIONS:

$$7X - 5X + 16 - 16 = 5X - 5X + 32-16$$

THEN:

$$2X = 16$$
$$2X/2 = 16/2$$
$$X = 8$$

SLIDE #6

On the right side of the equation there are no more like terms so that nothing more can be done with it. On the left side the two terms containing X can be combined and the term with constants can be simplified. Performing those operations, $7x + 16 = 5x + 32$.

Now to isolate the x, we move it from one side of the equation by subtraction. I chose the right side because that would result in a positive x rather than a negative. It could be done the other way.

Since the decision has been made to

to move all of the x terms to the left side of the equation, the constants must now be moved to the right. The inverse operation of +16 is to subtract it. This yields 2x = 16.

The indicated operation on x is to multiply it by 2. The inverse operation is to divide leaving x on the left and a number on the right. The equation is now solved.

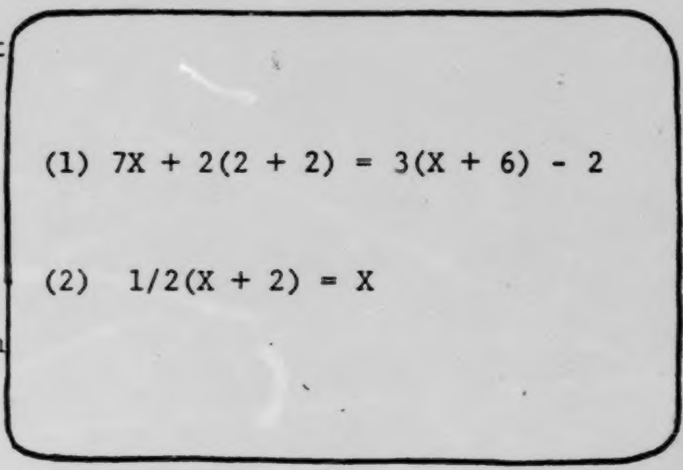
Look at slide number seven. See if you can solve the problems which are presented here.

Now look at slide number eight.

Look at slide number nine.

The answers to the problems presented on slide number seven are presented on slides numbers eight and nine.

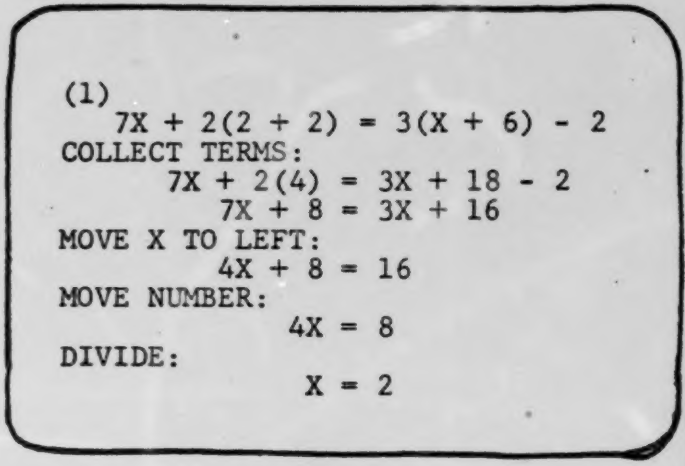
Look at slide number ten. Ratios and proportions are often used in chemistry. A ratio is expressed as the quotient of two numbers; a proportion as an equation. Three halves is a ratio; x = Ky represents a proportion. It could also be expressed as x over y = K.



(1) 7X + 2(2 + 2) = 3(X + 6) - 2

(2) 1/2(X + 2) = X

SLIDE #7



(1)

7X + 2(2 + 2) = 3(X + 6) - 2

COLLECT TERMS:

7X + 2(4) = 3X + 18 - 2

7X + 8 = 3X + 16

MOVE X TO LEFT:

4X + 8 = 16

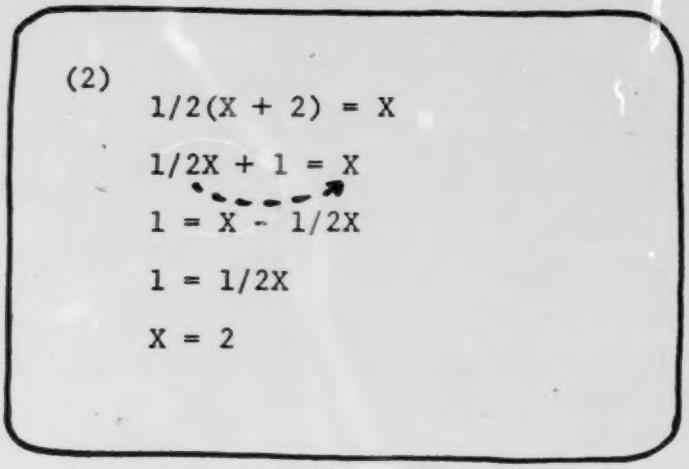
MOVE NUMBER:

4X = 8

DIVIDE:

X = 2

SLIDE #8



(2)

1/2(X + 2) = X

1/2X + 1 = X

1 = X - 1/2X

1 = 1/2X

X = 2

SLIDE #9

RATIO: $3/2$

PORPORTION $x = Ky$

constant of proportionality

$x/y = K$

SLIDE #10

VERBAL STATEMENT:

VOLUME IS DIRECTLY PROPORTIONAL TO TEMPERATURE

MATHEMATICAL STATEMENT:

$V = KT$

SLIDE #11

STATEMENT:

VOLUME IS INVERSELY PROPERTIONAL TO PRESSURE

MATH STATEMENT: $V = K\,1/p$

SLIDE #12

Advance to slide number eleven. Volume is directly proportional to Temperature and is expressed as $V = KT$. The constant is necessary because volume and temperature are not equal but proportional. The constant would depend on how much pressure there is, what the volume is and what the units being used are.

Look at slide number twelve. An inverse proportion simply means the reciprocal of. Volume is inversely proportional to pressure and is expressed as $V = K\ 1/p$.

Look at slide number thirteen.

If volume is directly proportional to temperature and inversely proportional to pressure, the two expressions are multiplied together. The product of constants is also a constant and so, since we know neither of them, we lump them together.

Look at slide number fourteen. See if you can solve the problem which is presented here.

Now advance to slide number fifteen. Here you will find the answer to the problem listed on slide fourteen.

STATEMENT:

VOLUME VARIES DIRECTLY WITH TEMPERATURE AND INVERSELY WITH PRESSURE:

$V = KT\ (K\ 1/p)$

The Product of Constants is Constant

SO:

$V = K\ T/P$

OR:

$PV/T = K$ OR ANY OTHER ARRANGEMENT

SLIDE #13

X IS DIRECTLY PROPORTIONAL TO A AND INVERSELY PROPORTIONAL TO B.

WHAT DOES B EQUAL?

SLIDE #14

X is directly proportional to A and inversely proportional to B. What does B equal?

$X = KA$

and . . $X = K\ 1/B$

so . . $X = K\ A/B$

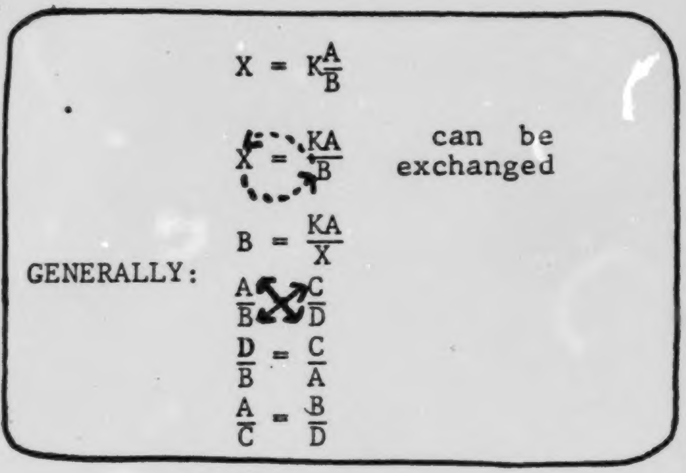
then $BX\ X = KAB/BX$

$B = KA/X$

SLIDE #15

Look at slide number sixteen. If a number multiplies a fraction it multilies the numerator only. This is why K times A over B can be written KA over B.

The problem can be solved more easily by simply exchanging means and extremes. This trick works in an equation that has a single term on each side, and only in that case, but the case is quite common.



$X = K\frac{A}{B}$

$X = \frac{KA}{B}$ can be exchanged

$B = \frac{KA}{X}$

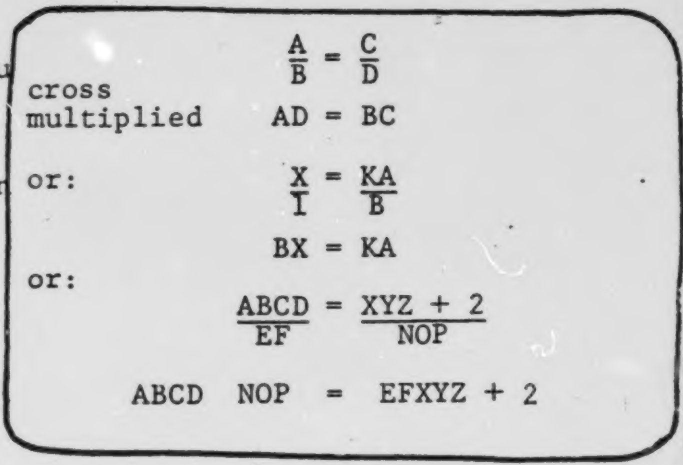
GENERALLY: $\frac{A}{B} = \frac{C}{D}$

$\frac{D}{B} = \frac{C}{A}$

$\frac{A}{C} = \frac{B}{D}$

SLIDE #16

Look at slide number seventeen. You may also cross multiply to get rid of the fractions. Again this operation can be used only when there is only one term on each side of the equation. It cannot be used if anything is added or subtracted to either or both sides.



$\frac{A}{B} = \frac{C}{D}$

cross multiplied $AD = BC$

or: $\frac{X}{I} = \frac{KA}{B}$

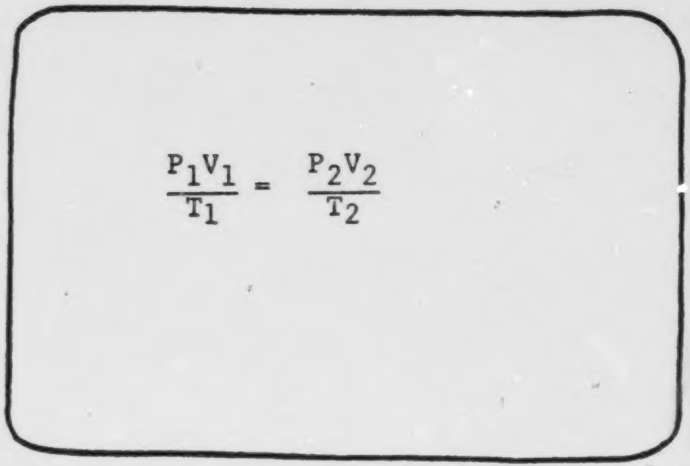
$BX = KA$

or: $\frac{ABCD}{EF} = \frac{XYZ + 2}{NOP}$

$ABCD\ NOP = EFXYZ + 2$

SLIDE #17

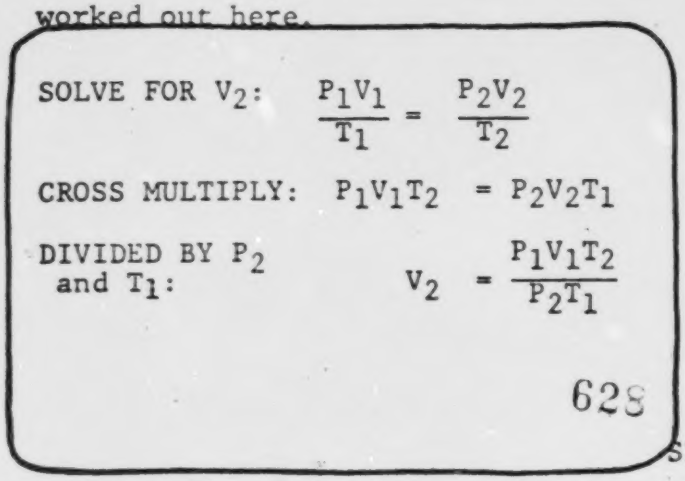
Look at slide number eighteen. Solve the equation for V sub 2.



$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

SLIDE #18

Look at slide number nineteen. The problem from slide eighteen is worked out here.



SOLVE FOR V_2: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

CROSS MULTIPLY: $P_1V_1T_2 = P_2V_2T_1$

DIVIDED BY P_2 and T_1: $V_2 = \frac{P_1V_1T_2}{P_2T_1}$

SLIDE #19

LOGARITHMS

Module R5, Logarithms, is the fifth in a series of five self-help modules. In order to work with this module you will need a log table.

Advance your slide carrousel to slide number one. A logarithm is the exponent or power of 10, or some other base that makes it exponentially equal to a particular number. The number 25 is equal to ten raised to the 1.3979 power. The value of 1.3979 is called the logarithm of 25. The number 558.9 is equal to 10 raised to the 2.7473 power. We say that the logarithm of 558.9 is 2.7473.

$25 = 10^{1.3979}$

1.3979 = the logarithm of 25

$\log 25 = 1.3979$

$558.9 = 10^{2.7473}$

$\log 558.9 = 2.7473$

SLIDE #1

Since logarithms are nothing but exponents of 10, all of the rules that apply to handling exponents apply to logarithms.

Look at slide number two. Here you will find a quick review of the rules for handling exponential numbers. To multiply exponential numbers, add the exponents. Ten to the 5th times 10 squared is 10 to the 7th.

WHEN MULTIPLYING EXPONENTIAL NUMBERS TO THE SAME BASE, ADD THE EXPONENTS:

$(1 \times 10^5)(1 \times 10^2) = 1 \times 10^7$

base

$(A^x)(A^y)(A^z) = A^{(x+y+z)}$

WHEN DIVIDING EXPONENTIAL NUMBERS TO THE SAME BASE, SUBTRACT THE EXPONENTS:

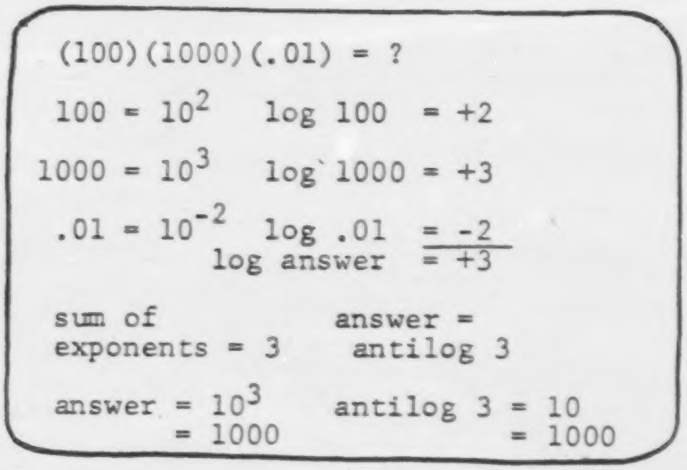
$$\frac{1 \times 10^5}{1 \times 10^2} = 1 \times 10^{5-2} = 1 \times 10^3$$

SLIDE #2

To divide exponential numbers, subtract the exponent of the denominator from the exponent of the numerator. Ten to the 5th power divided by 10 to the 2nd power is 10 to the 3rd power.

If you are shaky on the rules for handling exponents and the scientific notation form of writing numbers, it might be well to review module R3. Both skills are necessary for this module.

Look at slide number three. The problem is arithmetically trivial but let us look at how logarithms are applied to it. 100 is 10 to the second power. Its logarithm is therefore 2. 1000 is 10 cubed so that its log is 3. 0.01 is 10 to the minus 2.



(100)(1000)(.01) = ?

100 = 10^2 log 100 = +2

1000 = 10^3 log 1000 = +3

.01 = 10^{-2} log .01 = -2

log answer = +3

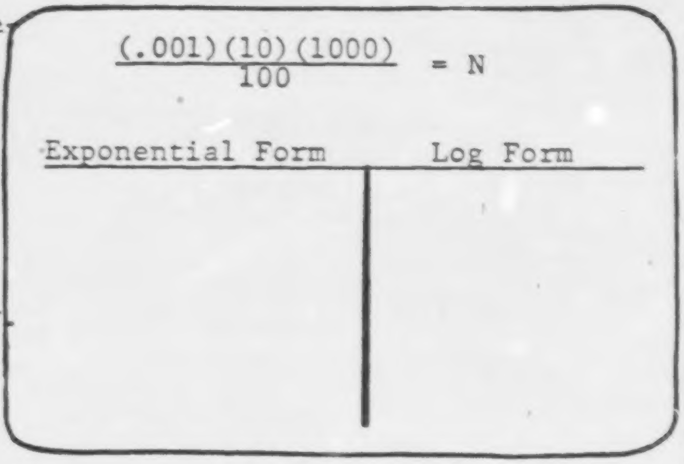
sum of exponents = 3   answer = antilog 3

answer = 10^3 = 1000   antilog 3 = 10 = 1000

SLIDE #3

To multiply we add exponents, therefore, we add logs. The term antilog means find the answer in ordinary numerical form.

Look at slide number four. Make 2 vertical columns on your piece of paper. Work the left hand column using exponential form. In the right hand column use logarithm form.



$$\frac{(.001)(10)(1000)}{100} = N$$

Exponential Form	Log Form

SLIDE #4

Look at slide number five. Notice how the steps correspond and really only the terminology changes.

See Page 512A - Following

SLIDE #5

Look at slide number six. So far the problems have been simple, but the plot thickens when we get involved with numbers other than powers of 10. 128 can be written as 1.28 times 10 to the second power. The log of 128 is then the log of 1.28 + log 10 to the 2nd power. Log 10^2 is simply 2 and is called the characteristic. The log of 1.28 can be looked up in a table of logarithms.

$128 = 1.28 \times 10^{+2}$

$\log 1.28 = .1072$ - Mantissa

$\log \underline{10^{+2}} = \underline{+2.000}$ - Characteristic

$\log 128 \quad 2.1072$

Characteristic Mantissa

or:

$128 = 10^{2.1072}$

SLIDE #6

Look at your log table. The column under N or No, contains the numbers between 1 and 10. The table may say 10, 11, 12, etc., or even 100, 110, and so on, but it is always understood that the decimal is after the first figure. Therefore the first entry has a value of 1.0.

The row of numbers across the top is the next digit in the number. For example, if you need the log of 1.00 you look up 10 in the N column and move over to the 0 column.

LOG TABLE WITH LOG 6.27 INDICATED

SLIDE #7

Look at slide number seven. The logarithm of 6.27 is circled. What

$$\frac{(.001)(10)(1000)}{100} = N$$

EXPONENTIAL	LOG
$.001 = 10^{-3}$	Log $.001 = -3$
$10 = 10^{1}$	Log $10 = +1$
$1000 = 10^{3}$	Log $1000 = +3$
Sum of Numerator Exponents	Log Numerator +1
$-3 + 1 + 3 = 1$	Log $100 = +2$
$100 = 10^{2}$	
Sum of Exponents = Numerator-Denominator	Subtract Log Denominator
$1 - 2 = -1$	Log $N = 1 - (+2) = -1$
$N = 10^{-1} = 1/10$	$N = \text{antilog}^{-1} = 10^{-1} = 1/10$

SLIDE #5

happens if you had a number with more than 3 significant figures? You could get a more precise log table, interpolate on this one, or round off the number. For our purposes we will round off the number.

Advance to slide number eight. Look up the log of 777. Remember it is 7.77 x 10^2. Its value is 2.8904.

Advance to slide number nine. Find the logs of the numbers indicated here.

Now look at slide number ten. The answers to numbers on slide nine are presented here. Notice that the log of the last example comes out negative. It may be represented as 8-10 or as a negative value. It will work either way.

Look at slide number eleven. Looking up antilogs is simply the reverse of looking up logs. You look in the field table to find the nearest value to your antilog.

Suppose you want to find the antilog of 2.9048. The 2 tells you that the number must be multiplied by 10 squared or 100. Looking in the field of the table one cannot find 9048 exactly but

LOG TABLE WITH LOG 7.77
INDICATED

SLIDE #8

LOG 28

LOG 86543

LOG .0154

SLIDE #9

LOG 28 = Log 2.8 + Log 10^1
Log 2.8 = .4472
Log 10^1 = 1.0000
Log 28 = 1.4472

LOG
86546 = Log 8.65 + Log 10^4
= .9372 + 4
= 4.9372

LOG
.0154 = Log 1.54 + Log 10^{-2}
= .1875 + (-2)
= 8.1875 - 10 OR -1.8175
notice

SLIDE #10

ANTILOG 2.9048 = ?

LOOK FOR IN FIELD OF TABLE

FROM TABLE, 9047 IS CLOSEST

9047 CORRESPONDS TO 8.03

THE CHARACTERISTIC IS 2

THEREFORE: 8.03×10^2

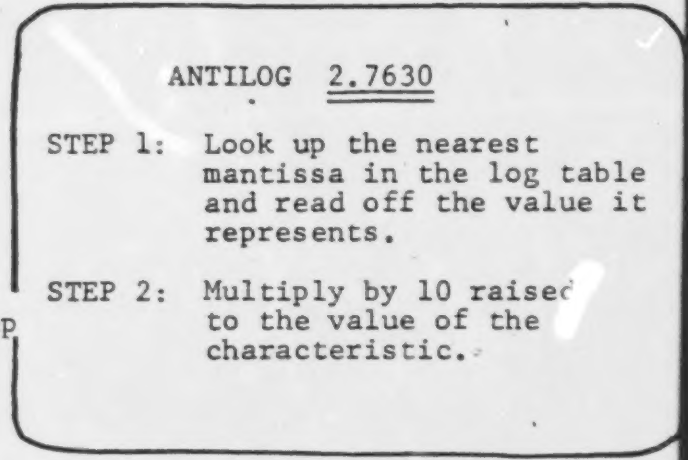
ANTILOG 2.9048 = 803

SLIDE #11

R 5 11

9047 is closest. It corresponds to a value of 8.03. Therefore, the antilog of 2.9048 = 803.

Look at slide number twelve. Find the antilogs of the log values listed here.



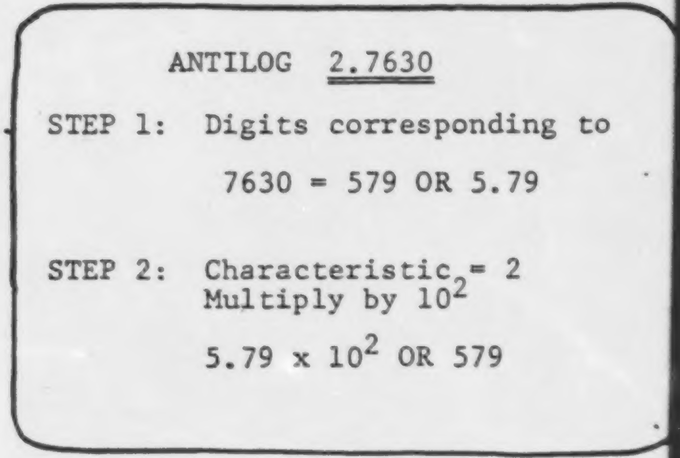
ANTILOG 2.7630

STEP 1: Look up the nearest mantissa in the log table and read off the value it represents.

STEP 2: Multiply by 10 raised to the value of the characteristic.

SLIDE #12

Look at slide number thirteen. Step 1 said to look up the mantissa in the table. We find 7627, corresponding to digits 579, to be the closest. The mantissa is 2 so the answer is 579.



ANTILOG 2.7630

STEP 1: Digits corresponding to

7630 = 579 OR 5.79

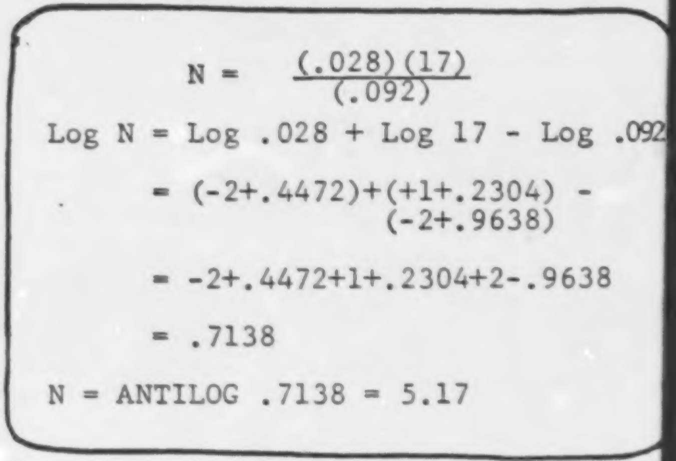
STEP 2: Characteristic = 2

Multiply by 10^2

5.79×10^2 OR 579

SLIDE #13

Now advance to slide number fourteen. M = .028 times 17 divided by .092. Using logarithms, log of n = log of .028 + log of 17 - log of .092. The first two logs are added because the two numbers are multiplied. The log of .092 is subtracted because it is the denominator.



$$N = \frac{(.028)(17)}{(.092)}$$

$$\text{Log } N = \text{Log } .028 + \text{Log } 17 - \text{Log } .092$$

$$= (-2+.4472)+(+1+.2304) - (-2+.9638)$$

$$= -2+.4472+1+.2304+2-.9638$$

$$= .7138$$

$$N = \text{ANTILOG } .7138 = 5.17$$

SLIDE #14

The characteristic of log .028 is -2 placed below in red. The characteristic of 17 is 1 and .092 is -2. The mantissa of 2.8 is +.4472. The mantissa of 1.7 is +.2304 and the digits 9.2 is +.9638.

Look at slide number fifteen. The 9-10 system is a perfectly good way to handle logs except when we come to pH

$$N = \frac{(.028)(17)}{(.092)}$$

$$\text{LOG } N = \text{LOG } 028 + \text{LOG } 17 - \text{LOG } .092$$

$$= (8.4472-10) + 1.2304 - (8.9638-10)$$

$$\begin{array}{rl}
 & 8.4472-10 \\
+ & 1.2304 \\
\hline
 & 9.6776-10 \leftarrow \text{SUM OF FIRST TWO} \\
 & -8.9638+10 \leftarrow -\text{DIVISOR} \\
\hline
 & +0.7138
\end{array}$$

ANTILOG .7138 = 5.17 as before

SLIDE. #15

problems. pH is defined as a negative log which forces you away from the 9-10 system. Since pH is probably the only contact with logs in chemistry, it might pay to look at slide number fourteen again.

Look at slide number sixteen. See if you can work the problems which are presented here.

$$N = \frac{128}{(.096)(54.2)}$$

SLIDE #16

Look at slide number seventeen. Here you will find the answers to the problems on slide number sixteen.

$$N = \frac{128}{(.096)(54.2)}$$

$$\begin{aligned} \text{Log } N &= \text{Log } 128-(\text{Log } .096 + \text{Log } 54.2) \\ &\equiv 2.+.1072- [(-2.+.9823)+(1.+.7340)] \\ &= 2 + .1072 + 2 - .9823 - 1 - .7340 \\ &= + 3 - 1.609 \\ &= + 1.3909 \end{aligned}$$

$$\begin{aligned} \text{Antilog } 1.3909 &= \text{Antilog } .3909 \times 10^1 \\ &= 2.46 \times 10^1 \\ &= 24.6 \end{aligned}$$

SLIDE #17

Advance to slide number eighteen. Roots and powers are easily calculated with logs. Just look up the log of the number, multiply by the root or power, and look up the antilog.

To find the cube of 25, we look up log 25, multiply by 3, and look up the antilog.

$$25^3 = ?$$

$$\begin{aligned} \text{Log } 25^3 &= 3 \log 25 \\ &= 3(1.3979) \\ &= 4.1937 \end{aligned}$$

$$\begin{aligned} \text{Antilog } 4.1937 &= \text{Antilog } 1937 \times 10 \\ &= 1.57 \times 10^4 \end{aligned}$$

SLIDE #18

Finally, look at slide numbers nineteen, twenty, and twenty-one. If, after studying this material, you still encounter difficulty with logs and antilogs, you should seek the aid of an instructor.

(SEE FOLLOWING A, B and C PAGES FOR SLIDE NUMBERS NINETEEN, TWENTY, AND TWENTY-ONE.)

$$\sqrt[3]{27} = ?$$

$$\sqrt[N]{K} = K^{1/N}$$

THEREFORE: $\sqrt[3]{27} = 27^{1/3}$

$$\text{LOG } \sqrt[3]{27} = 1/3 \text{ LOG } 27 = 1/3(1.4314)$$

$$= .4771$$

$$\sqrt{27} = \text{ANTILOG } .4771$$

$$= 3$$

SLIDE #19

$$\sqrt{\pi} = \overset{\text{2 IS UNDERSTOOD}}{\sigma\sqrt{3.14}}$$

$$= \sqrt[2]{3.14}$$

SLIDE #20

$$\sqrt{\pi} = \sqrt[2]{3.14}$$

$$\text{LOG.}\ \sqrt{\pi} = 1/2\ \text{LOG}\ 3.14$$

$$= 1/2\ (.4969)$$

$$= .2484$$

$$\text{ANTILOG}\ .2484 = 1.77$$

SLIDE #21

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APPENDIX A

LABORATORY ACTIVITIES

This appendix contains an overview of the laboratory activities included in each of the modules.

MODULE D1

1. DENSITY DETERMINATION: The density determination activity begins with the discussion of slide number fourteen. In this activity, the student determines the density of four different unknown liquids. The mass of the unknowns is determined using a scale and the volume using a graduated cylinder.

   Unknown solutions. The four unknown solutions are (1) tap water, (2) local sea water, (3) salt water of 100 o/oo, and (4) salt water of 200 o/oo.

   Materials. The activity requires the following materials: (1) a balance or scale, (2) one graduated cylinder, (3) four small bottles, (4) a quantity of salt, (5) tap water, and (6) local sea water.

2. ELECTROLYSIS: This activity is shown in its setup condition on slide number twenty-three. Dilute acid is electrolyzed in the activity using the electrolysis tubing and a DC power supply.

   Materials. The activity requires the following materials: (1) electrolysis tubing, (2) a DC (direct current) power supply, (3) a quantity of dilute acid, (4) two pieces of hookup wire, and (5) a stand to support the electrolysis tubing.

3. NEUTRALIZATION OF ACIDS AND BASES: In the activity, the student attempts to neturalize an acid (containing phenolphthalein as an indicator) by adding base in a dropwise manner. The base is added using an eyedropper. The activity begins on slide number twenty-six.

   Materials. The activity requires the following materials: (1) .5M HCl, (2) .1M NaOH -- this will allow one drop of acid to neutralize five drops of base, (3) phenolphthalein, (4) one 200 ml beaker, (5) two 50 ml beakers, (6) a 10 ml graduated cylinder, (7) one test tube.

4. ACID - METAL REACTION: This activity begins on slide number twenty-seven. The activity requires the student to drop some .1N H_2SO_4 on zinc chips, and results in damage to the zinc. The objective is to show the student an example of a reaction between metals and acids.

   Materials. The activity requires the following materials: (1) zinc chips, (2) .1N H_2SO_4, (3) one 200ml beaker, and (4) an eyedropper.

5. MARBLE - ACID REACTION: The activity begins on slide number twenty-eight. In this experiment the student reacts .1M H_2SO_4 with marble chips ($CaCO_3$) and observes the evolution of hydrogen gas.

   Materials. The following materials are necessary for the conduct of the experiment, (1) two or three marble chips, (2) .1M H_2SO_4, and (3) one test tube.

6. SILVER CHLORIDE PRECIPITATION: The activity is described along with the discussion surrounding slide number fifty-eight. The activity is intended to show the precipitation of sliver chloride by the addition of silver nitrate to a sample of local sea water. The silver chloride will occur as a white precipitate.

   Materials. The following materials are required to conduct this experiment: (1) local sea water, (2) silver nitrate, (3) one 200 ml beaker.

MODULE D2

1. The basic information for this activity is contained on slide number twenty-one of Module D2. The test procedures are outlined on page 7 of Chemical Analysis of Water by Drew Chemical Corporation.

   Materials. The following materials are required in order to conduct this investigation: (1) standard soap solution, (2) one 10 ml automatic burette with pressure bulb, (3) one two-hole rubber stopper, 16 oz. reagent bottle, (4) one 58.3 ml graduated cylinder soap hardness shaker bottle, and (5) a quantity of water from the carboy marked "Boiler A". This solution should be mixed in accordance with instructions given for that boiler. These instructions are provided in Appendix B, Stock Solutions.

2. This activity begins on slide number twenty-three. Slide twenty-three shows the equipment and includes tests number three and four in the Drew Chemical Company manual cited above (pages 8 and 9 in the manual). These tests are titled Phenolphthalein Alkalinity and Total Alkalinity and should be run using water from the carboy labeled "Boiler A".

   Materials. The equipment required for these tests is the same for both tests and is as follows: (1) one 10 ml automatic burette with pressure bulb, (2) one two-hole rubber stopper, 16 oz. reagent bottle, (3) one 50 ml graduated cylinder, (4) one evaporating dish, and (5) one 1 oz. dropping bottle.

   Reagents. The Phenolphthalein Alkalinity test requires the following reagents: (1) Drew phenolphthalein indicator and (2) Drew sulfuric acid. The Total Alkalinity test requires the following reagent: (1) Drew total alkalinity indicator. These reagents need not necessarily be those manufactured by Drew Chemical Company. However, they should be the same strength as those of Drew.

3. The activity begins with slide number twenty-four. This slide shows the equipment necessary to conduct Drew test number six, Chloride Test - Boiler Water listed on page twelve of the Drew manual. This test uses the sample left from running the test listed in #2 above.

   Materials. The following materials are required for the conduct of this test: (1) one 10 ml antomatic burette, (2) one pressure bulb, (3) one two-hole stopper and one 16 oz. reagent bottle for silver nitrate, (4) one 50 ml graduated cylinder, (5) one evaporating dish or glass flask, (6) Drew phenolphthalein indicator, (7) Drew sulfuric acid, (8) Drew potassium chromate, and (9) Drew silver nitrate.

4. This test begins with slide number twenty-five. This is Drew Chloride Test Alternate and is listed on page 12 of the Drew manual.

Materials. The test requires materials the same as are listed for the test in #3 above. The test uses water from the carboy marked "Makeup Feedwater and Potable Water".

5. The discussion of this test beings with slide number twenty-six. This test is titled, Condensate Salinity Test and is listed on page A-10 of the Bull & Roberts Marine Instruction Manual, Boiler and Feedwater Conditioning.

Materials. The following materials are required to run this test: (1) one one-liter bottle, (2) one 50 ml graduated cylinder, (3) Bull & Roberts chloride indicator (potassium chromate), (4) one burette, (5) Bull & Roberts chloride test solution (silver nitrate), and (6) a sample from the carboy marked "Makeup Feedwater and Potable Water".

6. These three tests begin with slide number twenty-seven. They are listed on pages A-5 and A-6 of the Bull & Roberts manual and are titled, (1) Total Alkalinity - A Reading, (2) Chloride Test (Salinity), and (3) Caustic Alkalinity - B Reading.

Materials. Test number one requires the following materials: (1) one 50 ml graduated cylinder, (2) one 500 ml flask, (3) Bull & Roberts alkalinity indicator (Phenolphthalein), (4) one alkalinity test solution burette, (5) Bull & Roberts alkalinity test solution (N/30 acid), and (6) a water sample from the carboy marked "Boiler A".

Test number two requires (1) Bull & Roberts chloride indicator test solution (silver nitrate), and (2) the burette mentioned above.

Test number three requires (1) one 50 ml graduated cylinder, (2) one 500 ml flask, (3) Bull & Roberts alkaline indicator (4) Bull & Roberts barium chloride solution, and (5) one burette as listed above.

7. These tests begin with slide number thirty. One of the tests, Colorimetric Phosphate Procedure Vanadomolybdate Method, is listed on page A-7 of the Bull & Roberts manual. The second test, Excess Phosphate - Boiler Water, is listed on page 16 of the Drew manual.

Materials. Both of these tests use samples from the carboy marked "Boiler B".

7. Materials. -- Continued

The Bull & Roberts test requires the following: (1) filter paper, (2) 5-10 ml viewing tube, (3) Bull & Roberts Vanadomolybdate Reagent, (4) distilled water, (5) one Bull & Roberts comparator, and (6) two 200 ml flasks.

The Drew test requires (1) powdered stannous chloride, (2) Drew molybdate reagent, (3) one glass funnel, (4) filter paper, (5) one combination phosphate mixing and comparator tube, (6) one stopper, (7) one phosphate comparator block (10 through 80 ppm), and (8) one brass measuring cup.

8. This test begins with slide number thirty-two. The test is listed on page B-3 of the Bull & Roberts manual and titled, Determination of Broxgon in Boiler Water (Iodine Demand Method).

Materials. The following materials are required to conduct this test: (1) one Bull & Roberts casserole, (2) Bull & Roberts Broxgon indicator, (3) one 10 ml graduated cylinder, (4) Bull & Roberts Broxgon #1 (dilute hydrochloric acid) reagent, (5) Bull & Roberts Broxgon #2 (potassium iodide) reagent, (6) one 50 ml graduated cylinder, (7) one stirring rod, (8) Bull & Roberts Broxgon #3 (potassium iodate) reagent, and (9) a sample of water from the carboy marked "Boiler B".

9. This test begins with slide number thirty-three which shows the equipment necessary in order to conduct the test. The test is listed on page 18 of the Drew manual and titled, Sulfite Test. It is labeled test #12.

Materials. The test requires the following materials (1) Drew standard potassium iodide-iodate solution, (2) Drew dry starch acid indicator, (3) one 10 ml automatic burette (for standard potassium iodide-iodate), (4) one 100 ml casserole graduated cylinder, (5) one stirring rod, (6) one brass measuring dipper, and (7) a sample of water from the carboy marked "Boiler B".

10. The test begins with slide number thirty-four. The test and its associated procedures are listed on pages D-2 and D-3 of the Bull & Roberts manual. The test is titled Colorimetric Control Test.

Materials. The following materials are required to run the test (1) one Hellige or Lovibond comparator block, (2) one special blue color disc No. 190-D for the comparator, (3) Bull & Roberts thymol blue indicator, and (4) a sample of water from the carboy marked "Boiler C".

11. This test begins with slide number thirty-five and is listed on pages 15 and 16 of the Drew manual. The test is titled Hydrazine Test and is listed as test number 9.

Materials. The test requires the following materials: (1) Drew hydrazine reagent (para-dimethylaminobenzaldahide - 2% in 1N - H_2SO_4), (2) one Drew hydrazine comparator block (range 0.0 to 0.5 ppm hydrazine) (N_2H_4), (3) one comparator test tube - etched 5 and 10 ml divisions, (4) rubber stopper, and (5) a sample of water from the carboy marked "Boiler C".

12. This test begins with slide number thirty-six. It is listed on page A-21 of the Bull & Roberts manual. It is titled Testing Boiler Water Samples.

Materials. The following materials are required in order to accomplish this sequence, (1) a thermometer, (2) one 50 ml beaker or graduated cylinder, (3) Bull & Roberts alkalinity indicator (phenolphthalein), (4) Bull & Roberts TDS reagent solution (N/10 acetic acid), and (5) Bull & Roberts conductivity cell.

13. This test begins on slide number thirty-seven. It is listed on page 26 of the Drew manual and is titled Dissolved Solids Determination in Condensate by Specific Conductance (test #15).

Materials. This test should be run on water from the carboy marked "Boiler B". The following materials are required: (1) conductance meter, (2) one green band cell for the conductance meter, (3) phenolphthalein, (4) gallic acid, (5) one stirring rod, and (6) sample of water from the carboy marked "Boiler B".

NOTE: The solutions for all carboys are listed in Appendix B, Stock Solutions.

MODULE C1

1. INTRODUCTION: Slide number twenty shows the equipment required to conduct this activity. Slide number twenty-one shows the setup of the equipment. The activity is designed to show the corrosion of zinc over copper when the two exist in a corrosive atmosphere.

Materials. The following materials are necessary for the successful conduct of this activity: (1) steelwool, (2) one balance, (3) one alligator clip, (4) one 500ml beaker, (5) copper sulfate, (6) one zinc electrode, and (7) one copper electrode.

MODULE C2

There are no laboratory activities associated with this module.

MODULE C3

There are no laboratory activities associated with this module.

MODULE C4

There are no laboratory activities associated with this module.

MODULE B1

There are no laboratory activities associated with this module.

MODULE A1

There are no laboratory activities associated with this module.

MODULE E1

There are no laboratory activities associated with this module.

MODULE E2

There are no laboratory activities associated with this module.

MODULE E3

There are no laboratory activities associated with this module.

MODULE E4

1. INTRODUCTION: The activity starts with slide number four. Slide four describes the use of the water analyzer. Slide number five continues the discussion started with slide four. Slide number six lists the actual test. This test is listed in the Drew Chemical Company Ultra Marine Vessel Record Book. The ammonia test is also included in the student lab book in the Ameroid Ultra Marine Abridged test guide section and in the Ameroid test procedures section.

   Materials. The following materials are required in order to successfully complete this activity: (1) a 25ml sample from the carboy marked boiler C, (2) 25ml of distilled water, (3) 250mm long form Nessler tube, (4) one water analyzer base, (5) one 1 ml graduated cylinder, (6) one 10 inch stirring , (7) one ammonia comparator slide, (8) one 2 oz. bottle marked Nessler Reagent with dropper pipette marked at 0.5/1.0cc, and (9) one cc Nessler reagent.

2. INTRODUCTION: The information for this test begins in the tapescript just after the slide number six information. This is the Water Analyzer Hydrazine test. Instructions for this test are contained in the Ameriod Ultra Marine Abridged test guide and Ultratest Procedures section of the student lab book.

   Materials. The following materials are required for successful completion of the test: (1) one water analyzer base, (2) three Nessler tubes 150mm, (3) one 2oz. stoppered bottle graduated at 25ml, (4) one dropper pipette marked at 0.5/1.0cc, (5) one 100ml graduated cyliner, (6) one 2 oz. stoppered amber glass bottle, (7) one hydrazine comparitor slide (8) hydrazine reagent A, (9) hydrazine reagent B, and (10) hydrazine reagent solution.

3. INTRODUCTION: The description of this activity begins with slide number nineteen. It is further described on page 10 of Practical Water Treatment for Marine Boilers 800 PSIG to 1500 PSIG by Magnus Maritec Corporation. It is titled pH Test Water Analyzer Method.

   Materials. The following materials are required for the successful completion of this test: (1) water samples from several carboys, (2) one water analyzer, (3) 3 water analyzer tubes marked at 150mm, (4) one pH comparitor slide, (5) meta cresol purple: pH range 7.6 - 9.2 (for condensate), (6) tolyl red: pH range 10.0 - 11.6 (for boiler water), (7) phthalein red: pH range 8.6 - 10.2 (for boiler water), (8) one 100ml graduated cylinder (9) one 10 inch stirring rod, and (10) 3 one oz. dropper bottles with .5ml pipette.

4. INTRODUCTION: This test starts with slide number twenty. It is discussed in the Magnus Maritec manual on page 9 and titled Low Phosphate Test.

Materials. The following materials are required for the successful completion of this test: (1) a sample from the carboy labeled boiler B, (2) one low phosphate slide comparitor 0 to 25 ppm, (3) one slide comparitor base, (4) 5 test tubes marked at 5ml, (5) 2 low phasphate stopper mixing tubes graduated at 10ml and 14ml, (6) 1 plastic dispensing cap for use on the molybdate reagent plastic bottle (or squeeze bottle), (7) 1 plastic funnel with filter paper, (8) dry stannous chloride powder #602-P, with plastic dipper attached, (9) molybdate reagent, and (10) distilled water.

5. INTRODUCTION: This activity begins with slide number twenty-two. It is titled, Silica Test - Water Analyzer Method and described on page 12 in the Magnus Maritec Manual.

Materials. The following materials are necessary for the successful completion of this test: (1) a sample of water from the carboy labeled boiler B, (2) one water analyzer support base with three tubes marked at 150ml; (3) one silica comparator slide 0.0 to 25ppm silica 2 - 2.5ml pipettes of 5ml measuring syringes, (4) one 50ml graduated cylinder, (5) one funnel, (6) filter paper, (7) one one-ounce dropper bottle (dropper etched at 0.5ml and 1.0ml), (8) one stirring rod, (9) silica reagent no. 1, (10) silica reagent no. 2, and (11) oxalie acid - 10%.

6. INTRODUCTION: This test is presented on slide numbers twenty-three and twenty-four. It is titled Hardness and further described in the laboratory manual in the Ameroid Ultra Marine Abridged test guide and Ultratest Procedures for sections.

Materials. The following materials are required for the successful completion of this test: (1) a sample of water from the carboy labeled boiler A, (2) 3 scoops of hardness buffer, and (3) 1 scoop of hardness indicator.

APPENDIX B

STOCK SOLUTIONS

STOCK SOLUTIONS

BOILER A

$NaCl$ - 1.32g } Dilute to 8 l → 100 ppm Ca

$CaCl_2$ - 2.20g } Dilute to 8 l → 275 ppm Cl

$NaOH$ - 10 ml 1.0N

BOILER B

$NaH_2PO_4 \cdot H_2O$ - .465g } Dilute to 8 l

Na_2SO_3 - .377g } Dilute to 8 l

$NaOH$ - 10ml 1.0N

BOILER C -- DREW

1) 1.0ml 64% $(NH_2)_2$ dilute to 1 l

put 10 ml diluted $(NH_2)_2$ in 8 l
first time only - 1 ml to recharge

2) Sulfite .59 in 8 l

Make up Feed:

.063 N NaCl 100 ml } dilute to 8 l

5 ml 1.0NNaOH } dilute to 8 l

BOILER C -- BULL AND ROBERTS

.5 ml 1.0N NH_4OH

dilute to 8 l

BOILER D

NaCl	2.0g	dilute to 8 l
$CaCl_2$	1.0g	
NaOH	15 ml 1.0	
$NaH_2PO_4 \cdot 2H_2O$	.75g	
Na_2SO_3	.75g	
$(NH_2)_2$	1.0 ml 6.4%	

BOILER D -- HI PRESSURE

to make 8 l

Boiler: PO_4 as $NaH_2PO_4 \cdot H_2O$ (20 ppm) = .232g (10-25ppm)

Cl al NaCl (10 ppm) = .132 g ($<$ 20ppm)

$(NH_2)_2$ as 6.4% solution (.1 ppm) = .0125ml ($<$ .1 ppm)

Dilute 100:1 and use 1.25 - 2 ml --

adjust by adding $(NH_2)_2$ until dissolved oxygen is removed

SiO_2 as $Na_2SiO_3 \cdot 9H_2O$ 10 ml stock ($<$ 25ppm)

stock = .1g in 1 l

(conductivity $<$ 500cm/cm)

conductivity can be increased by adding $NaNO_3$, KNO_3, sulfates, etc.

Cond Feed: pH -- adjust with NaOH if cond is low (8.3 - 9.0)
NH_4OH if cond near limit

NH_3 as NH_4OH, .1N = .2 ml

RANGES

Low Pressure

PO_4	0 - 80 ppm
Ca as $CaCO_3$	0 - 200 ppm
pH	8 - 10.5
TDS	0 - 500 ppm
Cl	0 - 340 ppm
$(NH_2)_2$	0 - .5 ppm
condensate pH	8 - 9.6

High Pressure

Boiler Water	PO_4	15 - 25	$(NH_2)_2$	.01 - .10
	pH	9.8 - 10.2	SiO_2	$<$6 ppm
	Cl	-16	P alk	---
	Cond	$<$120 mmh	T alk	---
Condensate	pH	8.9 - 9.0		
	NH_3	$<$.5 ppm		
Feed	Cond	---		
	Hardness	---		
	P alk	---		
	T alk	---		